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The Sand-Blast Cleaning of Structural Steel.

On page 457 of the previous volume appeared an abstract of a paper which set forth some of the results which have been attained in the use of the sand-blast in cleaning steel plates and structural steel.

The importance of this paper—which was read by Mr. Lilly before the American Society of Civil Engineers, and which appears in Vol XXIX, pp 130-152, of the Transactions of that Society—led to the consideration of placing before our readers the full text and illustrations, which we are enabled to do by the courtesy of the author. The table of costs, which was given in the abstract in dollars and cents, has in this article been rendered into pounds and shillings.

DURING the past few years some attention has been given to attempts to secure thorough cleaning of structural steel before the application of the preservative coating; but, unfortunately, we are still far from the realisation of the kind of work which should be required. Much has been written relative to the kind of paint which will best preserve the steel and iron used so extensively in a great variety of structures. In the discussion, which has been going on for many years many have argued very strenuously against, and many just as earnestly in favor of, perhaps every kind of paint now used largely as preservatives of ferric structures from the ravages of rust and corrosion. But in the discussion they have often lost sight of the very important matter of cleaning the steel properly. On account of the great deterioration of such structures, in the past, whether by reason of exposure to the weather on land or at sea, or to the action of acids, or the gases and moisture of coal combustion, in combination with the oxygen of the atmosphere, this is a question of vital interest to all engineers and others concerned in their erection or maintenance. Nevertheless, comparatively little has been done towards securing such cleaning as will insure a much longer life for, as well as economy in the maintenance of, such structures. The dawn of a better day seems to have appeared, in the application of better methods, in some instances, on new work, and, in more cases, on the old; and it is to be hoped that the full light of that day may soon be seen, in the results on new work in the shop—as a provision for the future—and on old structures—to undo, as far as possible, the neglect of the past.

It has often been observed that mill marks made with paint of a very inferior quality have afforded good protection to steel, while other portions, covered with a much better paint, have been much

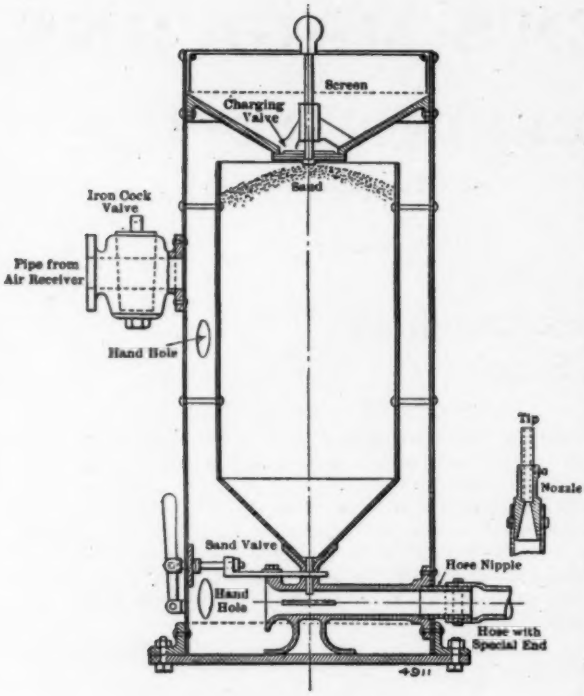


FIG. 1.—TILGHMAN'S SAND-BLAST APPARATUS

affected by rust, the latter even extending under paint which, for the most part, has still retained its continuity and elastic qualities. The explanation is found in the facts that the mill marks were made when the metal was clean, and that the paint applied subsequently was spread upon the mill scale, rust and grease which had accumulated upon it before the shop work was finished. However excellent may be its qualities, it is absurd to expect any paint to preserve steel to which it is applied, unless the mill scale, rust, dirt and grease have been first removed. This observation applies with equal, or it may be said, with even greater, force, to the repainting of old structures which have been neglected, and upon which rust and corrosion have proceeded so far that it is impossible to secure good preservation by ordinary methods of cleaning. Having this knowledge in mind, it is proper to determine, from the conditions met in any case, what is necessary to be done in order to insure that the preservative coating shall be applied only after the surface of the metal is clean and in proper condition to receive it. To accomplish this, there is no doubt that much of the new as well as old steel will be required to be cleaned by means of the sandblast, as the only practicable and effective method. Much of the steel, after leaving the mills, is stored out-of-doors and exposed to the weather for a considerable length of time before the shop work is done. Thus its rusting often progresses to such an extent that the ordinary process of cleaning with wire brushes, even if that be attempted, is not sufficient to permit the paint to come into immediate contact with and become firmly adherent to the metal. The quality of the paint used, on new structures as well as old, is an important matter; but that cannot be discussed in this paper.

The effectiveness of the sandblast process depends upon the ability of sand, used as a projectile, to break up, wear away and remove the substances against which it is directed, when actuated by a current of compressed air. All the machines, often called mixers, for the application of this process, are intended to secure the introduction of the proper proportion of sand into a current of compressed air passing through a pipe. This current of compressed air, bearing with it the sand thus introduced, is then directed into and through rubber hose, preferably $2\frac{1}{4}$ or $2\frac{1}{2}$ ins. in diameter, and a steel or iron nozzle of suitable size, and against the surface to

be cleaned. Sometimes the air-blast alone may be used to remove dust and soot. Such an appliance was first invented and patented by General Benjamin C. Tilghman, the patent being issued on October 18th, 1870. This appliance, as improved by Mathewson, is still on the market.* In this apparatus, a slotted slide, operated by a lever, regulates the quantity of sand introduced into the current of air. This is shown by the sectional drawing, Fig. 1.

In the Paxson-Warren machine, Fig. 2, the feed of the sand is regulated by a revolving piece, or valve, which covers the opening in the bottom of the hopper to the extent desired to let the proper quantity of sand fall through it and into the air pipe.

In the machine patented by J. M. Newhouse, of Columbus, Ohio (shown in Fig. 3), the sand passes from the hopper at the bottom through an annular opening around the end of a nozzle-shaped steel piece, which decreases in its outer circumference towards the end; and, by raising or lowering it, this annular opening may be increased or diminished in size. The distinguishing feature of this appliance is the use of this nozzle as a syphon, with its perforations as shown. The small holes permit part of the air which flows through the small pipe and the syphon to escape outwardly through the surrounding sand, thus stirring it up, and preventing it from clogging at the opening. A similar syphon, without the perforations, is placed in the air-pipe.

Possibly there are other machines, but the writer is not familiar with them. Any of the sand mixers may be made with two chambers, with valves arranged so as to lock the sand through the upper one into the lower one while the sand-blast is in operation.

The greatest merit of the sand-blast is that it removes from the surface of the metal every trace of dirt, scale, rust, and grease, and the bright metallic surface is everywhere exposed and perfectly clean. This is an ideal condition to secure the strong adhesion of the paint, so that, as far as it is possible, it will protect the metal. The thoroughness of the cleaning effected by the sand-blast is noted especially upon metal surfaces which have been pitted by rust and corrosion to a considerable degree. The pits are thus cleaned as thoroughly as other places. It also reaches and cleans effectually every portion, in re-entrant angles and on the edges of the different sections of a beam, girder, or post, on and around rivet-heads, and in many other places either entirely inaccessible to the wire-brush or steel-scraper, or on which they are used with great difficulty and little effect.

Such places cannot be cleaned thoroughly

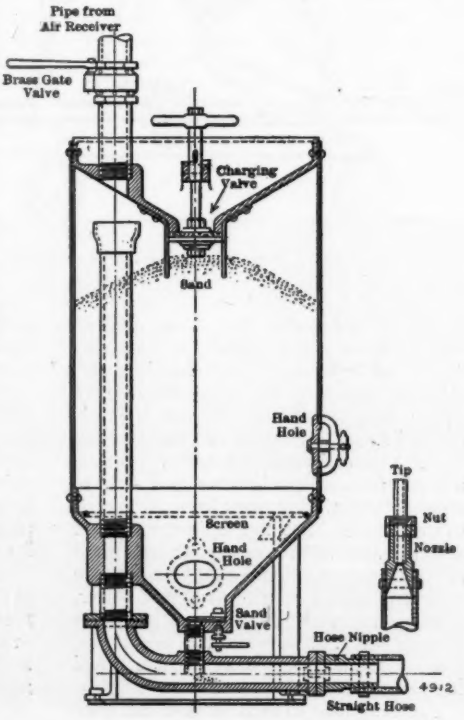


FIG. 2.—THE PAXSON-WARREN SAND-BLAST APPARATUS.

* Made by the Tilghman Patent Sandblast Co., Broadheath, near Manchester.

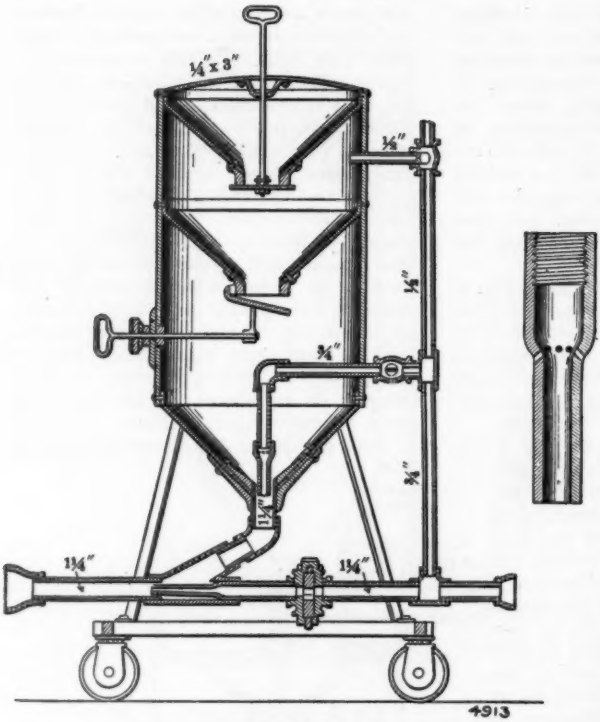


FIG. 3.—THE NEWHOUSE SAND-BLAST APPARATUS.

by hand, even with the most diligent effort. Even plane surfaces of considerable area on old structures requiring repainting, especially where covered largely with scales and rust, cannot be thus cleaned so as to remove all the dirt, rust, scale, and disintegrating paint. There will still remain sufficient rust and scale to separate slightly the paint from the metal, so that there is not the intimate contact and firm adhesion necessary to prevent the rusting process. The continuity of the coat of paint will soon be broken at places, and moisture and gases in the atmosphere coming in contact with the metal rust will be formed even under places where the paint remains intact.

Paints applied to such surfaces can often be stripped off like the peel of an orange, and still remains tough and elastic. Good paint it may be, but it has never taken a good hold of the steel. On the other hand, the writer has seen a piece of old steel, which was cleaned and painted with red lead in 1899, on which the paint will not peel off at all, but may be cut away, still leaving the under portion tightly adhering to the steel.

The sand-blast has been found serviceable and economical for other purposes than the cleaning of steel plates and structural steel. It is used in cleaning iron and brass castings, either by the direct application of the blast, or by introducing the sand-blast through the hollow trunnion of the tumbling barrel in which the castings are placed. The inner, as well as the outer, surfaces of castings are thus cleaned, and the sharp lines of the edges preserved, while the cleaning effected by the tumbling barrel without the sandblast tends to round off corners. Its use to clean street-railway rails and fish plates, for cast and electric welding, is familiar to all. It is also quite effective in cleaning cut-stone work. One ice-manufacturing company has recently purchased a sandblast machine for use in removing from its condensor pipes the lime scale formed from the hard water used.

A railway company has made use of it in cleaning about 18 ins. in length of a large number of its iron trolley poles, just above and below the surface of the ground. At this point the poles had rusted to such an extent as to weaken them materially,

and it would have been necessary to replace many of them. After cleaning in this way, a coat of paint was immediately applied, and, soon afterwards, each pole was encased in a cylinder of cement mortar tamped into removable forms.

The sandblast has also been used at the shops of several railways, in cleaning the tenders of locomotives before repainting. A great saving of expense is thus realised and superior work is obtained. It would be attempting too much to take up the methods and relative costs in these various lines of sandblast work.

It seems that, beyond a few scattered experiments, only during the past six or seven years may be found any published record of the application of this process to the cleaning of structural steel. And, even in these recent years, no very great amount of such cleaning has been done. Most of the trials heretofore made have been upon a somewhat experimental basis, and yet something may be learned from them. It is still rather problematical as to how cheaply the mill scale, rust and grease could be cleaned from new steel plates and structural steel, if an efficient permanent plant were provided for the purpose. Some new plates for the bilge keels of the *Massachusetts* were cleaned at the United States Navy Yard, Brooklyn, in April, 1897. With one nozzle, 3,155 sq. ft. of surface were cleaned in eleven hours. This is at the rate of 286·8 sq. ft. per hour. The cost of the work was 0·56 cent (·28*d.*) per sq. ft. Upon this basis the writer estimated that the sand-blast cleaning of new steel plates, I-beams and other sections, would cost from 50 cents (2*s.* 1*d.*) per ton, for very heavy sections, to $1·75 (7*s.* 3*d.*) per ton for light sections. This would not be a very large additional expenditure upon steel structures, considering the longer life which it would, no doubt, insure for the steel thus treated. The rapid deterioration and wasting away which has been observed on bridges and other structures may well cause builders of steel-frame buildings to consider the advisability of cleaning the steel in this way, before painting it and hiding it from inspection in the walls. The safety as well as the durability of such buildings may depend upon better provision against the rusting out of these steel frames. Who knows?

The steel for the anchorages of the cables of the New East River Bridge* were cleaned by the sand-blast. This was done for the special reason that it would be "buried in the masonry, and would be totally inaccessible for all time." This process was also used on some of the steel in the Boston subways. The writer has no figures as to the cost in these cases.

Much of the expense of repainting in the future would be saved if greater care were taken in securing thorough cleaning at the shops before applying the first coat of paint to new work. If this is to be accomplished, it will in many cases be

* Cf. FEILDEN'S MAGAZINE, p. 505, Vol. VII.

FIG. 4.—CORRODED I-BEAMS FROM A VIADUCT.

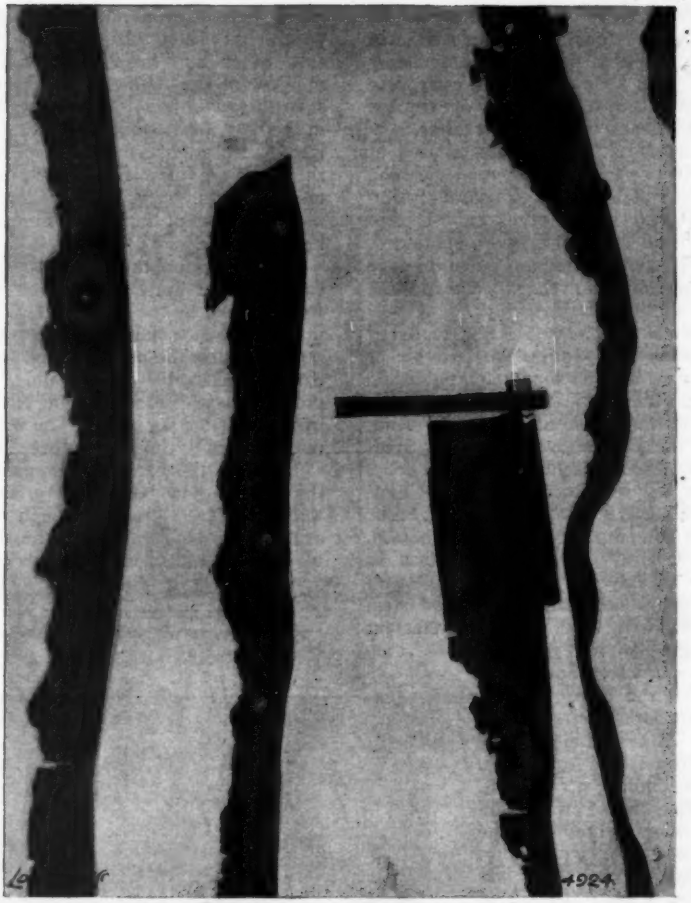


FIG. 5.—CORRODED FLANGE-ANGLES OF FLOOR STRINGERS.

found necessary to use the sand-blast; but this will not be done until the purchaser is willing to pay for it; and he must be convinced of its necessity and ultimate economy before he will be willing to do so. When there is a demand for it the shops will be equipped with the necessary machinery, and will be able to do it more cheaply. At present one shop has to bid against the other, and, none of them being required to make bids with such cleaning as a part of the specifications, the bids are such that the shops probably cannot afford to clean the steel properly, in some instances at least. They are averse to this process because of the expense of fitting up for it, the delay in getting the work out, and the cost of handling. Therefore the purchaser must be the prime mover in securing such work.

In the cleaning of old structures for

repainting, this process has been more extensively applied, and, therefore, there are better data relative to such work than as to the cost of cleaning new steel at the shops. The necessity of its use to preserve old structures requiring repainting is more apparent than the more remote future saving of the expense of its application for repainting, by a much smaller outlay to secure thorough cleaning before erection.

During the latter part of March and the first two days of April, 1897, the bottom of the United States steamship *Atlanta* was cleaned at the United States Navy Yard, Brooklyn, by means of the sand-blast. Its cost was 4·24 cents (2·12*d.*) per sq. ft.; but the work was done on a more or less experimental basis, and with the added experience of the past six years, and a more perfect plant, it could probably be done for much less.

The work done on the One Hundred and Fifty-fifth Street Viaduct, in New York City during the year 1897 is familiar to all.* The cost of this work was reported as averaging about 13 cents (6·5*d.*) per sq. ft., ranging from 20 cents (10*d.*), at the first, down to a little less than 10 cents (5*d.*), in the latter part of the work of cleaning 50,000 sq. ft. of surface. The pressure of compressed air then used was only about 20 lbs. at the sand-blast apparatus, which is without doubt too low a pressure for the efficient removal of scale such as had accumulated

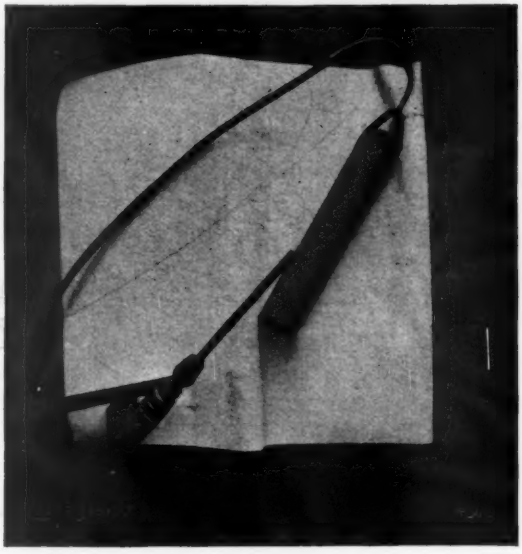


FIG. 6.—SAND-BLAST NOZZLE, REDUCER AND BLOWER.

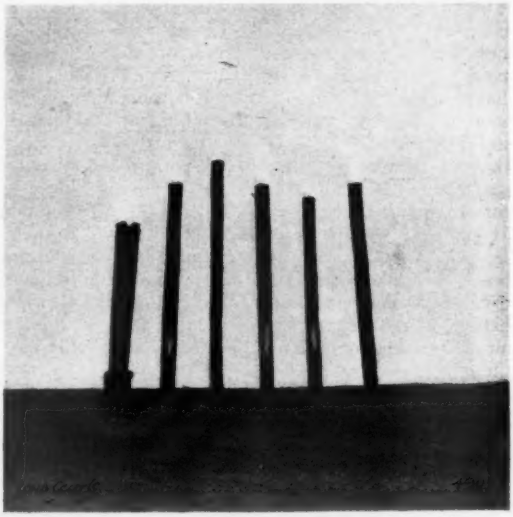


FIG. 7.—WORN-OUT SAND-BLAST NOZZLES.

* *Engineering News*, September 23rd, 1897, p. 198: *The Engineering Record*, September 25th, 1897, p. 356; and other engineering periodicals

FIG. 8.—SAND-BLAST NOZZLEMAN IN WORKING COSTUME.

there. It would seem, from recent experience, that a pressure of 35 lbs. would have been much more effective. This is true, because the viaduct was covered to a considerable extent with heavy rust scale and four layers of old paint, and a pressure of 35 lbs. would have made the sand projectiles much more efficient in breaking up and throwing off such scale. It was estimated that the 600,000 sq. ft. of the painting surface of the viaduct could be cleaned for about 7·5 cents (3·75*d.*) per sq. ft. It is quite probable that this could be done now at half that estimate; at least, on all portions of the viaduct except the members having a very small extent of surface, where much sand and air are wasted in missing the steel along the edges.

The next work of this kind reported upon was the cleaning of the iron lock-gates and a portion of the aqueduct of the Muscle Shoals Canal, during the years 1898 and 1899, under the engineers of the United States War Department. The first report of this, made before its completion, is found in the House Documents for 1898–9.* This covers the work done to June 30th, 1898; and, on page 1,926 it is stated that the cost for cleaning was about 2·3 cents (1·15*d.*) per sq. ft. In the report,† made after the completion of the work in 1899, the cost of cleaning 49,664 sq. ft., and painting it with red lead, is stated to be 0·0588 dols. (2·94*d.*) per sq. ft. Allowing a reasonable amount for the painting, it is probable that 3 cents (1·5*d.*) per sq. ft. would be very near the cost of the cleaning alone. In this case the plant was erected on a barge, roofed over, and was very well arranged to accomplish the work. The cost of the plant was included in this statement, and the same plant could be used for continuing such work. This cost was about one-third of the whole cost of cleaning and painting.

During the year 1899 the Pittsburg, Cincinnati, Chicago and St. Louis Railway Company used the sand-blast for cleaning the columns and girders supporting its buildings over the railway tracks, along the east side of the High Street Viaduct, in Columbus, Ohio. The girders support brick arches, and there are no buckle plates. They are subjected to the blast, gases and steam from the large number of locomotives passing to and from the Union Depot and goods and shunting engines passing under them at frequent intervals. This company also cleaned part or all of a bridge at Akron, Ohio. No accurate account was kept of the cost and the area cleaned; but, from the best available information, it is estimated to have been about 3 cents (1·5*d.*) per sq. ft. J. M. Newhouse, the inventor and patentee of the Newhouse sand-blast, is foreman for this company, and his apparatus was used in doing the work.

* War Department Reports, Engineers, Part 3, p. 1925 *et seq.*

† Engineer's Report, Part 3, p. 2289, House Doc. for 1899 to 1900.

The City of Columbus, Ohio, has six viaducts in the vicinity of the Union Station, by which the streets pass over the railway lines. All the railroads passing through the city, except one, enter and leave the Union Station under the Fourth Street Viaduct near the east end, and the High Street Viaduct near the west end; and some of them pass under each of the other viaducts, one to the west and three to the south-west from the High Street Viaduct. Besides the goods and passenger trains passing under them, much shunting is done under each by the yard engines. Hence, all these viaducts have been attacked seriously by rust and corrosion; and, on the portions most exposed to the blast, steam and gases from the locomotives, nearly all the paint has been destroyed and the metal consumed to a considerable extent. The Fourth Street Viaduct has been injured most, and two years ago it was cleaned by hand and repainted. This viaduct was erected in 1891, and was repainted in June, 1894; in September, 1896; and again, at the time above mentioned, in the fall of 1900. When the last repainting was progressing it was found necessary to replace with new ones seventeen of the 7-in. I-beams supporting the plank floors of the sidewalks over the rails most used by goods trains and yard engines. Fig. 4 is from a photograph of three of these I-beams taken after their removal, after nine years service. At the time this was done, the lower flange-angles of many of the stringers supporting the buckle-plates under the roadway had been rusted away until very thin; and in places the horizontal legs of the angles had been partly eaten away, so as to narrow them to about half their original width. These, however, were still considered of sufficient section to last for a time, and were not replaced then. The viaduct was painted under a contract,

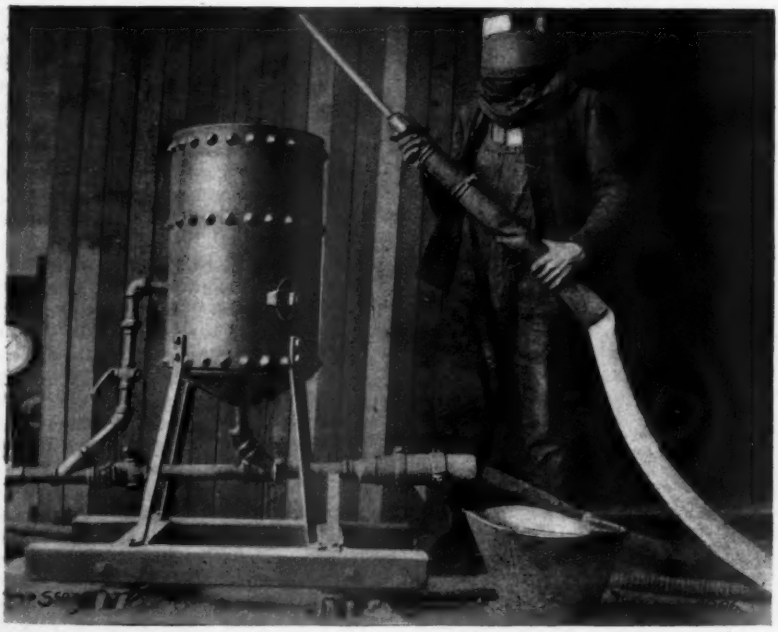


FIG. 9.—SAND-BLAST MACHINE, NOZZLEMAN AND SAND-DRYER

and considerable care was taken in trying to clean it as thoroughly as possible with steel scrapers, brushes, chisels and hammers. The hammers were often vigorously used to jar the scales loose by blows against the steel, and then scrapers, chisels and wire brushes used to complete the work.

At that time the sandblast was suggested by the Engineering Department, but was not used. With as thorough work as could be done, many scales, so tightly cemented to the steel that they could not be detached, were loosened, upon the application of the first coat of paint, by the softening effect of the oil acting upon the cementing rust. The paint then applied began to scale in places within six months thereafter, partly due to the inferior quality of the first coat of paint and partly to the rust, soot and scale left upon the steel when repainted. The flange-angles of the floor stringers continued to waste away, and, in the summer of 1902, it was found necessary to replace, by new ones, the two angles of the lower flange on each of ninety floor stringers. The need of this is apparent from Fig. 5, which is a photograph of some of the angles taken after their removal.

The new angles were surrounded with a covering of Portland cement mortar, one to two mixture, about ¾ to 1 in. thick. This was rammed under the lower surface of each beam, between it and a plank form, which was left to hold it against the steel until it had set for 48 hours. A wire netting, four meshes to the inch, secured by sheet-iron fasteners placed on the rivets as they were driven, was placed so as to surround the lower flange-angles before the cement mortar was applied. The cement covers the angles and netting completely, and is expected to protect them from rust. After seven months the cement is still intact and shows no sign of cracking.

In view of the rapid deterioration of the viaducts of the city, and the prospect of having to replace them in a few years unless something were done to arrest it, the city authorities were induced to adopt the sandblast as a means of cleaning them before repainting. The chief engineer of the Department of Public Improvements, had been very earnest in the advocacy of this course, believing it to be the only one that would be effective. Accordingly, in November, 1901, the work was commenced on the Front Street Viaduct, over the Little Miami Railroad, and 12,600 sq. ft. were cleaned and repainted, under the supervision of the writer as engineer in charge. When the weather became suitable for it, in April, 1902, the work was resumed, and continued on this and the other viaducts named until the middle of November. The cleaning done amounted in all, to 135,500 sq. ft. of surface. The cost and other data relative thereto are shown in Table No. 1. Four viaducts and the south span of the High Street Viaduct were completed. It is likely that the other three spans of the High Street Viaduct, and the Fourth Street Viaduct, will shortly be cleaned and repainted.

It was impracticable to secure good contract work at a reasonable price, and all the sand-blast cleaning, as well as the painting, was done by men hired by the day. Two Newhouse sand-blast machines, mounted on light trucks, so that they could be moved about and placed where convenient for the work, were used in cleaning the viaducts named in Table No. 1. A wire-bound 1½-in. rubber air-hose, 50 ft. in length, connected each machine with the 2-in. air-pipe. Old rubber hose, which was much cheaper than new, was used for the sand hose, part of it being 2¼ and part 2½ ins. in diameter. The nozzles used were ½-in. extra heavy gas pipe of various lengths, from 12 to 24 ins.; a length of at least 12 ins. seems to direct the blast with more effect than a shorter one. This was used instead of tool steel or other hard pipe because it was believed that it would last nearly as long and cost much less. The average length of time one nozzle lasted was about five hours, as shown by the length of pipe used and the total hours run. The nozzle was connected to the sand hose by a heavy specially cast reducer, about ¾ in. thick. This is shown in Fig. 6, which also shows a blower used at the High Street Viaduct. This reducer was made thick, to sustain the wear caused by the deflection of the sand into the

small nozzle pipe. The most severe wear of the nozzles is at a point 3 ins. from the connection with the reducer. The four worn nozzles in Fig. 7 show the characteristic form of the failure of the nozzles when worn out. The one at the right was selected as a rare exception, it being worn out at the outflow end. The three-part nozzle at the left wore out toward the centre, and also just outside of the bushing, in which the three ¼-in. pipes were set with babbitt metal. This nozzle was made only for the purpose of a test, which is recorded in Table No. 2. After the test, it was used until worn out, and lasted, in all, 1 hr. and 19 mins.

It will be noted that the sand in passing from the large sand hose to the small nozzle is deflected so as to produce a cross-fire, striking with greatest force against the sides of the small pipe near the reducer end. A like wear upon the rubber sand hose occurs near its connection with the pipe from the machine, which is a 1¼-in. pipe, and the spreading out of the sand to form the larger stream causes it to strike against the sides and then deflect to follow the direction of the hose. One foot in length, or sometimes a little more, cut from this end of the hose occasionally fitted it for further use. The length of sand hose used varied from 25 to 65 ft., being regulated by the distance of the work from the place where the machine had to be placed. As the machines could not be placed upon scaffolding in this work, at least 35 ft. of hose were required on nearly all the work, so as to reach from the ground to the floor system,

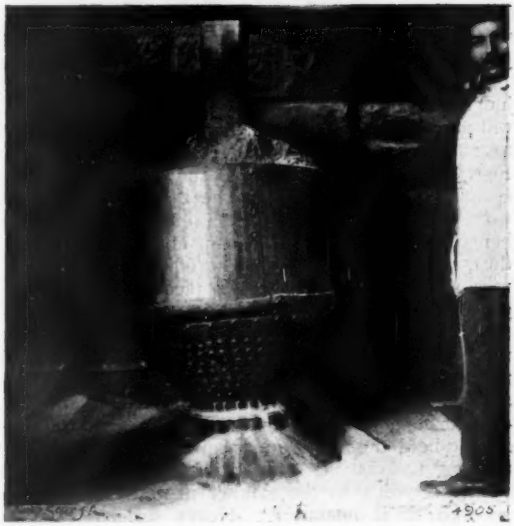


FIG. 10.—A SAND-DRYER.

FIG. 11.—SHOWING THE USE OF MOVABLE TRESTLES IN CLEANING A VIADUCT.

from 16 to 20 ft. above the tracks, and in some places out over the tracks as far as 30 to 40 ft.

The nozzlemen should be men of some judgment and intelligence, so that they will understand how to manage the nozzle to make the blast most effective. In Figs. 8 and 9 a nozzleman is shown in costume ready for work. The helmets worn were of tin, with cloth curtains hanging to the shoulders to keep out the dust, as far as possible. Instead of using wire gauze in the helmet, two pieces of glass were used for the nozzleman to see through, because it excluded the dust more effectually. When frosted over by rebounding sand, the glasses were removed and new ones inserted. After a little experience a good nozzleman will learn how to hold the nozzle in any given case, varying its distance from the working point according to the manner in which he finds it is operating. Heavy scale requires him to hold the nozzle close, and light cleaning can be done more rapidly by holding it farther away and permitting the blast to spread somewhat and thus cut a wider swath. On moderately hard places about 5 to 6 ins. is the proper distance. To make it clean most rapidly he must also direct the blast so as to cut a swath clean as he goes, passing first in one direction and then in the other, across the member being cleaned, so as to leave no spots to which he must go back and thus waste the force of the blast on clean metal around them. The nozzle should generally be directed so as to strike the surface at a slight inclination from the normal, say 20 to 30 degs. away from the nozzleman, thus blowing the dust and sand away. The cleaning should be carried forward from the nozzlemen, so that the blast will always act upon the exposed edge of scales, rust, or old paint, and, by getting under any loose portions, throw them off without first having to break them up.

The compressed air was supplied from a compressor with an air cylinder of 14 ins. diameter and a stroke of 12 ins., compressing the air to a gauge pressure of 50 to 60 lbs. The number of strokes was regulated automatically so as to keep the pressure nearly constant. The air was led from the compressor to a large receiver, and then, by a line of 2-in. steel pipe, to a small receiver at the viaduct where the work was to be done. From this receiver (having a capacity of about 9½ cub. ft.) the air was conducted to the sand blast machines. The pressure at the machines was usually from 30 to 40 lbs. The requisite length of 2-in. pipe varied from about 1,250 to 2,200 ft. The small receiver had a pet-cock in the bottom to let out accumulated water, and it removed much of the moisture from the air used.

The compressed air was paid for by the city at the rate of 40 and 45 cents (*1s. 8d.* and *1s. 10·5d.*) per hour for one machine, and 60 cents (*2s. 6d.*) per hour for two machines in operation. For 18 per cent. of the time only one machine was in operation. This made the work cost more, because two machines could have been operated for about one and one-half times what one would cost. A foreman, two nozzlemen, and three labourers could operate two machines and dry the sand for them. The foreman was paid 35 cents (*1s. 5·5d.*), nozzlemen 25 cents (*1s. 0·5d.*), and labourers 15 cents (*7.5d.*) during one-half of the time, and, after that, 17½ cents (*8·75d.*) per hour.

The sand used was from Lake Erie. An attempt was made to secure rather coarse, clean, and sharp sand; but it was at times impossible to do this without some delay, and some of the sand used was too fine and made much dust on account of the silt it contained. The sand was at first dried in two old locomotive ash-pans, with old ties for fuel. This required almost constant attendance by one man, to stir it up and keep it from becoming so hot as to make the grains brittle and ineffective.

About May 1st, 1902, the dryer shown in Fig. 10 was made by fitting a sheet-steel hopper on an old cast-iron stove. The wet sand would not fall through the ¾-in. holes in the lower part of the hopper, but would as soon as dry. The sand was permitted to cool for a few hours before being used, as hot sand caused steam and was likely to choke the small opening in the bottom of the hopper, around the end

of the syphon nozzle. The objection to this kind of a dryer is that the fire-pot, being surrounded by sand in contact with it, burns out in a short time. Two fire-pots were required in six-months' service.

All the viaducts named in Table No. 1 have buckle-plate floor systems, exposing a large amount of steel surface to the action of rust and corrosion. It may be well to state the conditions under which the work of cleaning had to be done, in order to give a better understanding of the items making up the cost. The data here given may then be better analysed and applied to any other proposed sand-blast cleaning. The first four viaducts named were erected during 1893 and 1894, and all were repainted during August and September, 1896, and none of them had been repainted since that time. High Street Viaduct was erected in the latter part of 1893, repainted in August, 1896, and again in October, 1899. The cleaning done before repainting, in each of these cases, was only hand-cleaning. All appearances indicate that the steel of the Front Street Viaduct over the Pittsburg, Cincinnati, Chicago and St. Louis, and the Cleveland, Cincinnati, Chicago and St. Louis Railways must have been in better condition than that of any of the other viaducts, and a better quality of paint must have been applied at the time of its erection. This is judged largely from the condition of the portions of the viaducts above the level of the street pavement, and protected by it from the direct action of the blast and gases from the loco-

FIG. 12.—PART OF GIRDERS AND BUCKLE-PLATES OF A VIADUCT. CLEANING NEARLY COMPLETED.

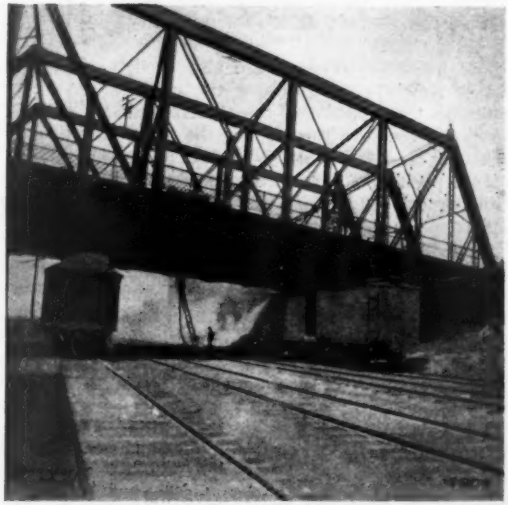


FIG. 13.—PART OF NORTH SPAN OF FRONT ST. VIADUCT, COLUMBUS OHIO.

motives. The portions below the pavement, on all the others, are subjected to greater wear by the locomotive blast on account of their small clearance above the stacks, their clearance above the level of the railroad tracks being only 16·33 to 16·75 ft., while this viaduct has a clearance of 20·33 ft. In cleaning them, therefore, it was impossible to swing any staging below the clearance elevation, in the case of four of them. The Front Street and the Naghten Street Viaducts do not afford sufficient space above the lower surface of the plate girders in which a man can work, and it was necessary to work from movable trestles, about 12 ft. high, made as light as possible, so that they could be moved off the tracks whenever a train or an engine was about to pass, and be replaced and the work continued when the track was clear. This may be seen in the view of the Front Street Viaduct, Fig. 11.

Under the first three viaducts mentioned in Table No. 1 there are two main tracks and one side track, with a spur track from the middle of the first, making four tracks under the east half of it. The photograph of this viaduct was taken from a point very near the outer rail of the side track and west of the viaduct, and does not show the other tracks.

The movable trestles were also used, part of the time, in cleaning the cover-plates on the bottoms of the girders and the portion of the work along the abutments of the Maple Street Viaduct; but a large portion of the cleaning was done from staging resting upon the lower cover-plates and angles of the plate girders. Fig. 12 shows a portion of the girders and buckle-plate when all, except a small portion of the buckle-plate and the web of the girders, where scale can be seen, had been cleaned and given a coat of red lead. Two more coats, of a paint less susceptible to the action of combustion gases, were applied afterwards, as on all the viaducts.

To secure the safety of the men while at work on these three viaducts when using the trestles over the tracks, it was necessary to have flagmen to give warning of the approach of trains, so that the trestles could be removed in time to avoid

TABLE No. 1.—Cost, etc., of Sand-Blast Cleaning of Viaducts.

Location of viaduct.	Cost of Labour.	Cost of flagmen.	Cost of compressed air.	Sand Used.		Dryer, Sand-blast, scaffolding, etc.	Total cost.	Number of square feet cleaned.	Cost per square foot.	Square feet cleaned with 1 cub. ft. of sand.	Square feet cleaned per hour by one sand-blast.	Average pressure at sand-blast in pounds per square inch.
				Cubic yards.	Cost.							
	£ s.	£ s.	£ s.		£ s.	£ s.	£ s.		d.			
Front St., over Little Miami Railroad...	80 5	9 8	29 1	54·00	16 7	11 13	146 14	24,900	·0141	17·1	64	35
Naghten St., ,, ,, ...	29 6	3 14	11 17	28·44	8 16	6 15	60 8	8,000	·0181	10·4	49	37
Maple ,, ,, ,, ...	46 9	2 13	19 12	34·50	12 1	12 5	93 0	17,000	·0131	18·2	66	35
Front St., over Pittsburg, Cincinnati, Chicago & St. Louis and Cleveland, Cincinnati, Chicago & St. Louis Railways	139 14	—	47 18	92·65	22 10	18 3	228 5	63,000	·0087	25·2	89	30
High St. (South Span)	198 3	—	66 17	129·91	33 12	25 10	324 2	22,600	·0344	6·1	23	33
Totals and Averages	493 17	15 15	175 5	339·50	93 6	74 6	852 9	135,500	·0177	14·8	54	33

the danger. On the Maple Street Viaduct flagmen were not needed for so large a proportion of the time as on the other two viaducts. The cost of flagmen alone amounts to about 0·2 cent (0·1*d.*) per square foot on the first two in Table No. 1, and 0·07 cent (0·035*d.*) on the Maple Street Viaduct. The time lost on account of trains and switch engines sometimes amounted to one-fourth of the working time. If there had been no interruption by trains, and if flagmen had not been required, a fair estimate, from approximate calculations, based on records of the time lost each day and the cost of flagmen, would reduce the cost for the work to about the following figures: Front Street Viaduct, 2·3 cents (1·15*d.*); Naghten Street Viaduct, 3 cents (1·5*d.*); and Maple Street Viaduct, 2·45 cents (1·2*d.*) per square foot. Matched flooring screens, fastened with copper nails, were placed immediately over the main tracks and under the floors of these three viaducts, to protect them from the blast from locomotives.

In the Front Street Viaduct, over the Pittsburg, Cincinnati, Chicago and St. Louis and the Cleveland, Cincinnati, Chicago and St. Louis Railways, in which the clearance was 20·33 ft., the staging was supported on iron hangers, which reached 2 ft. below the lower flanges of the floor beams. This space, with the 29 ins. more to the buckle-plates, gave room enough for the work, and the staging still gave about 2 ft. more clearance than the High Street Viaduct, just east of it and over the same tracks. Fig. 13 shows part of the north span of this viaduct, over the Cleveland, Cincinnati, Chicago and St. Louis Railway tracks. The portion of the three heavy trusses above the pavement was in very fair condition, and it was not thought necessary to clean it with the sand-blast. This saved the cleaning of 36,000 sq. ft. of metal surface on this viaduct, while on the others practically all was cleaned. A portion of this viaduct, shown in Fig. 12, is not over the railway tracks, and was not affected as seriously as the remainder of the floor system. Some of the paint was still good, and it was not all taken off. This, together with the fact that there was not much interruption to the work, made the cost of cleaning on this viaduct less than on any other, all the others being much affected with rust, scale and corrosion upon nearly all parts of them, even above the level of the pavement, where protected from the direct action of the gases.

The south span of the High Street Viaduct, the portion already cleaned, is over the main freight and passenger tracks, and yard engines pass under it frequently. The other spans can be cleaned for very much less than this one. It has been estimated by men who are in the employ of the Pennsylvania Railway Company that an average of from 250 to 300 engines pass under this span every 24 hours. The girders and buckle-plates were in very bad condition, and very heavy and exceedingly firm scale had been formed over large portions of them. This scale was firmly cemented to the steel by the rust and carbonates which had formed. As a consequence the sand-blast did not blow off much of it, nor did it work under the scale and throw it off as on the other viaducts. Therefore it cost nearly twice as much as the highest of the others, and nearly four times as much per square foot as the large Front Street Viaduct. The floor system is similar to that of the Maple Street Viaduct, the pavement being supported by seventeen plate girders. Immediately east of this is the structure under the roadway to the Union Station, also having seventeen plate girders. The distance over both is about 165 ft., and this, with the girders extending 3·5 ft. below the floor, causes the smoke to hang a long time between the girders after an engine has passed beneath. Often it does not clear away before another engine comes along and again fills all the spaces with dense smoke. The smoke, and the dust from the sand-blast work, therefore, caused a great deal of trouble. It was very difficult, and part of the time impossible, to get nozzlemen to keep both blasts in operation. To get rid of the smoke and dust an electric fan was tried for a short time, it being placed near the abutment between the girders where the work was progressing. This kept the smoke from rising, and cleared away the dust quite well, but the bearings were injured very much by

the dust and fine sand. Then the blower shown in Fig. 6 was made. This was connected with the air-pipe by a ½-in. rubber hose, and a jet of compressed air, passing through an opening of about $\frac{1}{32}$ in., and into and through a section of 5-in. sheet-iron pipe about 2 ft. long, set up a current of air, which, being directed along between the girders, was quite effective. One of these was made for each sand-blast, and they were used for a considerable portion of the time. Smoke and dust, however, would gather behind the blower, and be drawn through it at times, and it was not a complete success. It was effective for a distance of about 20 ft.

Another cause of the high cost of this work was the low pressure secured at the sand-blast machine during much of the time The operation of the blowers tended to reduce it, and the compressor was worked beyond its intended capacity, and was not at the time doing as good work as earlier. The average pressure at this viaduct, as stated in Table No. 1, is partly an estimate, as the gauge was broken, and for a portion of the time was not in use. When at 30 lbs. or less, the sand-blast was very slow in cutting the scale here encountered; but when at 38 lbs. to 40 lbs. it was much more efficient. Occasionally, when only one blast was in operation for a short time, the pressure would run up to 45 lbs., and then the effect was still better.

From the experience in sand-blast cleaning here given it may be stated safely that, for heavy scale and corrosion, in situations such as this High Street Viaduct, a pressure of from 35 lbs. to 45 lbs. per square inch is not any too high. On the other hand, very efficient work is done at a pressure of about 25 lbs., where only light scale, rust spots, and disintegrating paint are to be cleaned off. The labour costs approximately twice as much as the power, and increase of power is advisable where needed.

On all the cleaning done the bright surface of the steel, having almost the appearance of frosted silver, was exposed to view by the removal of every vestige of rust, scale, and old paint. The pitted portions, with a little more brushing, were as well covered with the paint as the others; and after one year it still holds on them as firmly, to all appearances, as when it first dried after being put on.

The paint was applied very soon after the sand-blast, and sometimes curtains of heavy muslin were stretched between the painters and the sand-blast to prevent the dust and sand from interfering with the painting. All surfaces cleaned were painted before night, and rarely was it necessary for the painters to work more than half an hour after the sand-blast was discontinued for the day. It is best to work with the wind, so that it will carry the dust and sand away from the painters and nozzlemen.

Some records of actual results are shown in Table No. 2, both in the ordinary work of cleaning and on tests in which an accurate account was taken for all the data presented therein. In some of these records there are omissions, because all the elements were not noted. The long-time records give only the surface cleaned, and not the sand used or the horse power necessary; and the two, showing results as to the whole work, are included for the sake of comparison. In these two are given some other results of calculations, from known quantities and records, which represent rates for one sand-blast, although two were running about 82 per cent. of the time. The number of hours stated is obtained by adding together the number of hours run by each machine. The tests of October 16th and 31st, 1902, were made in order to determine the relative effectiveness of nozzles of different diameters, from ¼ in. to ¾ in. in size. The sizes of pipe given are the nominal sizes of gas pipe, with "Ex. H." added where extra heavy gas pipe was used, which, of course, is smaller in interior diameter than standard gas pipe. The last one noted was with a nozzle (Fig. 7) made from three ¼-in. gas pipes, one end of each being inserted in a 1¼-in. by 1-in. bushing, and babbitt metal poured in to secure them there. While only made for an experiment, this nozzle gave very good results, it having the highest rate of cleaning in square feet per hour. It used considerable sand, about the same as the

TABLE No. 2.—Data as to the Operation of the Sand-blast; and Tests of Nozzles of Different Diameters.

Date.	Duration. Hours.	Duration. Minutes.	Nominal size of gas pipe nozzle.	Air Pressure. At compressor.	Air Pressure. At sand-blast.	Cubic feet of free air per minute.	Horse-power required.	Cubic feet of sand used.	Area cleaned in square feet.	Square feet cleaned per cubic foot of sand.	Rates per Hour. Cubic feet of sand.	Rates per Hour. Square feet cleaned.	Remarks.
1899.													
Sept. 27.....	...	29	½″	...	35	170	20·4	1·52	110	72·5	3·14	227·6	Pittsburg, Cincinnati, Chicago and St. Louis Railway work.
1901.													
Nov. 14.....	...	55	½″ Ex. H.	50	35	170	20·4	6·60	144	21·8	7·20	157·1	Plate girder, considerably rusted.
,, 16.....	...	26	½″ Ex. H.	50	36	...	...	2·20	77	35·0	5·10	177·7	Plate girder, paint nearly destroyed.
,, 14.....	4	45	½″ Ex. H.	50	35	170	20·4	.....	375	...	...	79·0	Plate girder (includes lost time).
,, 16.....	3	...	½″ Ex. H.	50	36	...	...	.....	322	...	...	107·3	Plate girder, paint nearly destroyed (includes lost time).
,, 18.....	7	50	½″ Ex. H.	50	36	...	...	.....	655	...	...	83·6	Plate girder, paint nearly destroyed (includes lost time).
,, 19.....	7	30	½″ Ex. H.	50	35	...	...	.....	825	...	...	110·0	Plate girder, paint nearly destroyed (includes lost time).
,, 20.....	7	30	½″ Ex. H.	40	25	...	...	.....	1,227	...	...	164·0	About 10% of paint good and not removed (includes lost time).
Dec. 7.....	13	30	½″ Ex. H.	48	33	...	...	.....	1,000	...	...	74·1	Floor system over railroad tracks (includes lost time).
Nov. 14, 1901 to Aug. 13, 1902	1,519	...	½″ Ex. H.	...	33	...	...	5,658·9	112,900	20·0	3·72	74·3	First four viaducts in Table No. 1.
1902.													
Aug. to Nov....	990	...	½″ Ex. H.	...	33	...	...	3,507·6	22,600	6·4	3·54	22·8	High Street Viaduct, see Table No. 1.
Oct. 16.....	...	18	½″ Ex. H.	55	37	156	18·7	1·40	11·80	8·4	4·67	39·33	High Street Viaduct, test run.
,, 16.....	...	24	½″	55	37	140	16·8	1·31	6·65	5·1	3·28	16·63	High Street Viaduct, test run.
,, 16	...	27½	½″	55	39	108	13·0	1·20	2·42	2·0	2·62	5·28	High Street Viaduct, test run.
,, 20.....	...	27	½″ Ex. H.	...	35	...	...	3·30	18·70	5·4	7·67	41·60	High Street Viaduct (another blast running).
,, 31.....	...	7½	½″	55	40	200	24·0	1·10	4·25	3·9	9·10	35·20	High Street Viaduct, test run.
,, 31	...	18	½″ Ex. H.	55	41	170	20·4	2·20	14·00	6·4	7·33	46·67	High Street Viaduct, test run.
,, 31.....	...	9	½″	55	42	156	18·7	1·10	6·60	6·0	7·33	44·00	High Street Viaduct, test run.
,, 31.....	...	24	½″	55	43	130	15·6	1·00	4·75	4·7	2·50	11·88	High Street Viaduct, test run.
,, 31.....	...	7	½″	55	41	176	21·1	1·10	6·60	5·4	9·43	51.40	High Street Viaduct, test run.

$\frac{3}{4}$-in. pipe, but cleaned nearly one-half more.

All these tests were made on the High Street Viaduct, where for all of them the corrosion was as nearly as possible of the same character. The rates of cleaning are low, because on this viaduct the scale was so hard. These tests of nozzles were made with a sand hose 65 ft. in length. All the nozzles for these eight tests were 12 ins. long. It will be seen from the results that the $\frac{1}{2}$-in. extra heavy pipe, which is $\frac{3}{4}$ in. when worn out, is about the proper size for this kind of work.

Improvements can certainly be made in this apparatus. Some of the appliances were made as experiments, and are rather crude. One observation may be made which will occur to all, that more sand-blasts might be added with advantage, if sufficient power to run them were provided. The work at Columbus was limited to two machines, on account of the small capacity of the compressor. Perhaps a larger pipe to convey the air would have added to the pressure at the machines and to the effectiveness of the sand-blast. For ordinary cleaning of bridges and other structures not subjected to such hard treatment as viaducts situated where much exposed to the blast and gases from locomotives, it is safe to say that, with a more perfect equipment, sand-blast cleaning can be done at from $1\frac{1}{4}$ to 2 cents per sq. ft. The advantages anticipated for this kind of cleaning, especially where almost a necessity, because nothing else will do the work thoroughly, are to be gained by a careful inspection at intervals after it is done, and the repainting, with ordinary, good hand-cleaning, before the paint has been worn off so as to set up the vigorous rusting process which comes when air and moisture get to the metal. In such locations as the viaducts in Columbus it seems to be the only thing that will do the work. For future construction in similar locations let every engineer beware of the use of steel exposed to locomotive blasts, as these will wear out any paint. The life of those structures already in existence, and others which may be built in the future, should be extended as long as possible by the use of the best means that can be commanded.

GEO. W. LILLY, A.M.Am.S.C.E.

A New Integrating Planimeter,

with a Proof of the Theory of Planimeters as applied to the Integrating Pattern.

THE system of permanently recording the flow of water, electricity, etc., on diagrams revolved daily or weekly by clockwork, is very largely in use. Three sets of figures are usually required from each diagram, viz.:—1. The maximum rate of flow for any period. 2. The minimum rate of flow for any period. 3. The total quantity of water that has passed the gauging instrument during the time occupied by one, or a portion of one, complete rotation of drum, usually either 24 hours or 7 days.

The rates of flow are, of course, immediately read off the diagram, but the total quantity that has passed through the gauging instrument requires to be computed arithmetically. This, however, is a somewhat tedious process, and, moreover, the accuracy of the computation is dependent, to a certain extent, on the correct judgment of the person employed.

To get over this difficulty, a highly interesting planimeter has recently been devised by Mr. Bernard Bryan, of the East London Waterworks, Lea Bridge, which will give, with absolute accuracy the computation of any diagram obtained from a Deacon or Venturi meter, weirs or notch gauges.

This is done by simply passing the pointer over the lines made by the pencil of the instrument.

The feature which distinguishes the instrument from the ordinary planimeter consists in the arrangement of the roller, which is so made that the inclination of its axis to the tracing-arm can be varied, whereas in the ordinary planimeter the axis of the roller is fixed parallel to the tracing-arm.

By reference to the illustrations it will be seen that the tracing-arm is connected by a universal joint to an arm pivoted to the roller-frame.

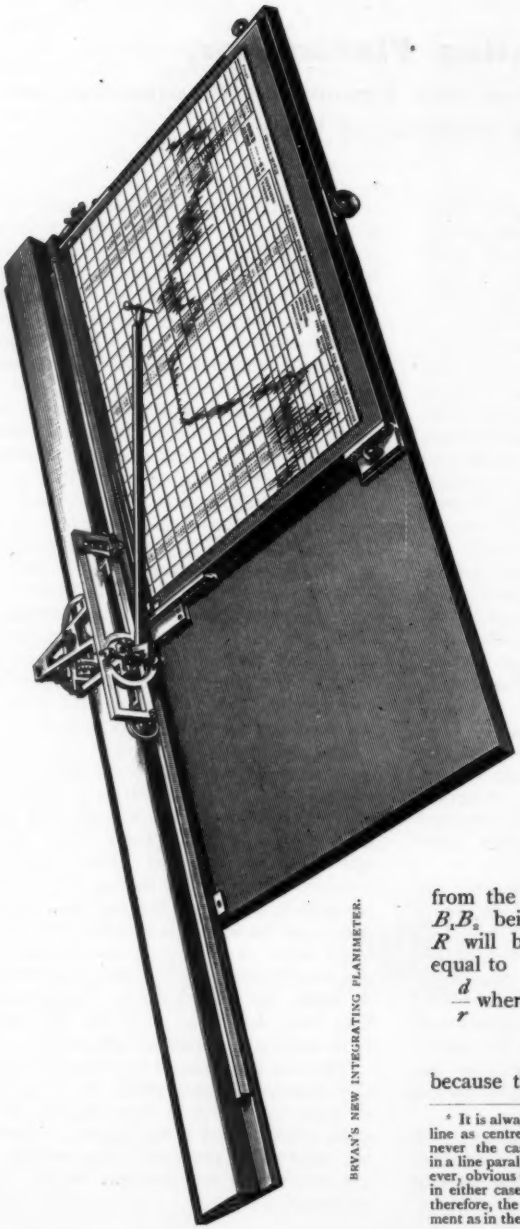
The roller-frame is pressed against a cam by means of a spring, the cam being attached to the three-wheeled truck which runs in a straight grooved rail. The in-and-out movement of the tracing-arm causes a corresponding motion of the roller-frame over the cam, thus altering the angle between the roller and the tracing-arm.

The cams are so arranged as to be easily changed, and by fitting a suitable one, the movement of the tracing-point round the diagram enables the total number of gallons passed to be read off direct from the roller and vernier.

The diagram is clipped on to a board, on which the instrument is mounted. The tracing-arm is then passed over the pencil lines registered on the diagram form, and the total quantity of water which has passed through is read off directly from the divided xylonite roller and vernier. The diagram form is then removed and filed for future reference.

The planimeter is made in various sizes according to the purpose for which it is intended to be used. It is possible to use one instrument for a variety of purposes; thus the diagrams from weirs and notch gauges and various sizes of Deacon and Venturi meters can all be integrated, if desired, on one planimeter, and it can be made to suit diagrams from other sizes of recording instruments at any time desired. The instrument, which is made by the Palatine Engineering Co., Ltd., Liverpool, can also be made to be used as an ordinary planimeter.

The cam is graduated from the theoretically correct diagram which it is desired to compute. This is done because it is quite possible that some diagrams in printing may vary 1 per cent.; the readings of the instrument are therefore in any case accurate.



BRYAN'S NEW INTEGRATING PLANIMETER.

* Proof of Theory of Planimeters (not Polar).

Let BA be a rigid rod which can revolve around centre A, and which can with the centre move in a straight line CD. (Fig. 1, page 119.)

At any distance from the centre A let a roller R be placed, with its axis coinciding with the centre line of the rod (hereafter called the tracing arm) and its plane of rotation at right angles to its axis. The circumference of R will come in contact with the plane surface to be measured at a point on the circumference, plumb below the centre line AB of the rod

If the tracing arm be moved any length AA on the line CD it is obvious that roller will not turn, its plane of rotation being at right angles to direction of motion of BA.

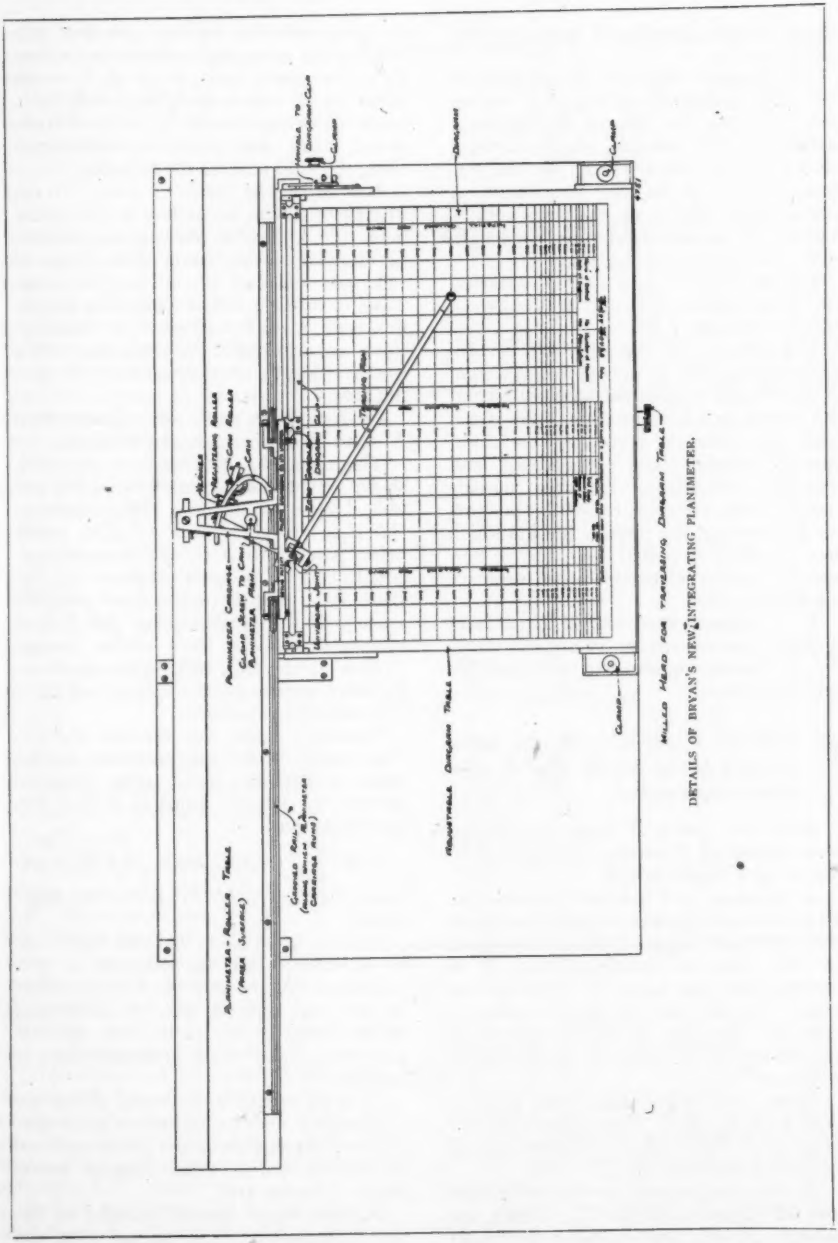
Let there be a tracer attached to the arm AB at B. From the centre A move the tracing arm radially until B assumes a position AB_1 at right angles to straight line CD. (Fig. 2.)

Let the roller be now so set that any angular motion in it can be seen later. On now moving the tracing arm from the position AB_1 to position $A_1 B_2$, $B_1 B_2$ being parallel to CD, the roller R will be revolved a number of times equal to

$$\frac{d}{r} \text{ where } r = \text{length of circumference of roller,}$$
$$d = \text{distance from } A \text{ to } A_1,$$

because the plane of rotation of roller is

* It is always here assumed that axis of roller is in same line as centre line of tracing arm. This is, in practice, never the case, the axis of roller being for convenience in a line parallel to centre line of tracing arm. It is, however, obvious that precisely the same angles will be assumed in either case, as the two centre lines are parallel; and, therefore, the same results are given in the practical instrument as in the theoretical one explained in following proof.



DETAILS OF BRYAN'S NEW INTEGRATING PLANIMETER.

parallel to the direction of motion of the tracing arm.

The distance recorded in any unit on the roller multiplied by length of tracing arm AB, gives the area of the rectangle $AA_1B_2B_1$. For example, let the circumference of the roller = 1 in., let the distance AA_1 = 10 ins., let the length of tracing arm AB = 15 ins., then area = number of revolutions of roller by length AB = 10 × 15 = 150 sq. ins.

Let the roller be read when the tracing arm is in position AB, and again when in parallel position A_1B^3.

It is obvious that the roller will revolve when tracing arm is moved radially from B to B_1; and if roller be again read when the tracing arm is in position A_1B_2, it will read this distance moved in excess of correct quantity (say 150 sq. ins.), and therefore erroneously. On again moving tracing arm *radially* back to position A_1B^3, however, the positive motion which was originally imparted to roller, is now exactly counterbalanced by the negative motion imparted.

It is obvious that for all equal and opposite movements in an angular direction by the tracing arm, the two errors are self-destructive.

To prove the theory when the arc moved through by the tracing arm is other than a right angle.

From the centre A move the tracing arm radially till B assumes a position AB_2 not at right angles to CD.

In this case, as it has been proved that all equal and opposite angular motion of the tracing arm imparting erroneous motion to the roller is self-destructive, it is assumed that the point of contact of the roller with the plane is plumb under A, and that therefore no angular motion is transmitted to the roller—it revolves about point A.

Move the tracing arm from position AB_1 to A_1B_2, B_1B_2 being parallel to CD (Fig. 3). Then roller will give area of figure (rectangle) $B_1B_2Z_1Z$.

Produce the plane of the roller in a straight line till it cuts A_1B_2 at C_1. Take the triangle AA_1C_1, and consider the roller as apart from the tracing arm, but still keeping the same angle relative to the line CD. In going from A to A_1 it could either travel askew along line AA_1, or it could roll along the side AC_1 of the triangle AA_1C_1, and slip (without registration) along the side C_1A_1 of the triangle.

Now in moving the roller from A to A_1, whether it travels along line AA_1 or along lines AC_1 and C_1A_1, the registration will be identical, as the angle of the plane of roller has not been altered in either case. Take it to have rolled from A to C_1; in this case it will register, and therefore show an area equal to the length AC_1, which × length of tracing arm will give the area.

Produce A_1B_2 to B_3 (Fig. 4), and from B_1 draw B_1B_3 perpendicular to A_1B_3.

The rectangle $AB_1B_3C_1$ is the area shown by the roller × length of tracing arm AB_2, by construction. The rectangle $AB_1B_3C_1$ = parallelogram $AB_1B_2A_1$, AB_1 being parallel to A_1B_3 (by construction, and Euclid I, 35, parallelograms on the same base and between same parallels are equal) the parallelogram $AB_1B_2A_1$ = rectangle $B_1B_2Z_1Z$ for a similar reason. ∴ Area of $AB_1B_3C_1$, which is area as shown by roller motion = area $B_1B_2Z_1Z$, which it was desired to evaluate.

Consider, again, the triangle AA_1C_1: The travel of the circumference of the roller = distance AC_1. The distance moved by tracing point = $B_1B_2 = AA_1$ (parallelogram).

Now $\frac{AC_1}{AA_1}$ = sin. angle AA_1B_2 = sin. angle ZAB_1; ∴ $AC_1 = AA_1$ × sin. angle ZAB_1.

Now it is obvious that the roller can be so divided and the diameter so proportioned that the area can be given direct in any units desired, without multiplying by the length of the tracing arm, which is a constant; and this is invariably done in practice.

∴ AC_1, which is the travel of the circumference of roller, and which is the area required (already proved) = distance moved by tracing point × sin. angular movement of tracing arm.

∴ over equal lengths, parallel to the line CD, moved by the tracing point, the

areas recorded vary as sin. angular movement of tracing arm.

Additional proof of areas recorded varying, over equal lengths, as the sine of the respective angles of tracing arm.

Let BA B_1A (Fig. 5) be the tracing arm at two different angles, BAC and B_1AC respectively.

Move the tracer and consequently the centre the two equal lengths BZ, B_1Z_1. Then the roller R will register the respective areas, as directly proportional to the sines of their respective angles.

Now the areas vary as $BC : B_1C_1$ (or as the respective heights), and $BA = B_1A$ (tracing arm).

$\therefore$ Area $BZEC$: area $B_1Z_1DC_1$ :: $\frac{BC}{BA}$ :: $\frac{B_1C_1}{B_1A}$ (dividing BC and B_1C_1 by BA).

$\therefore$ Area $BZEC$: area $B_1Z_1DC_1$ :: sin. BAC : sin. B_1AC_1.

To prove the theory when the figure, whose area is required, is a semi-segment of a circle.

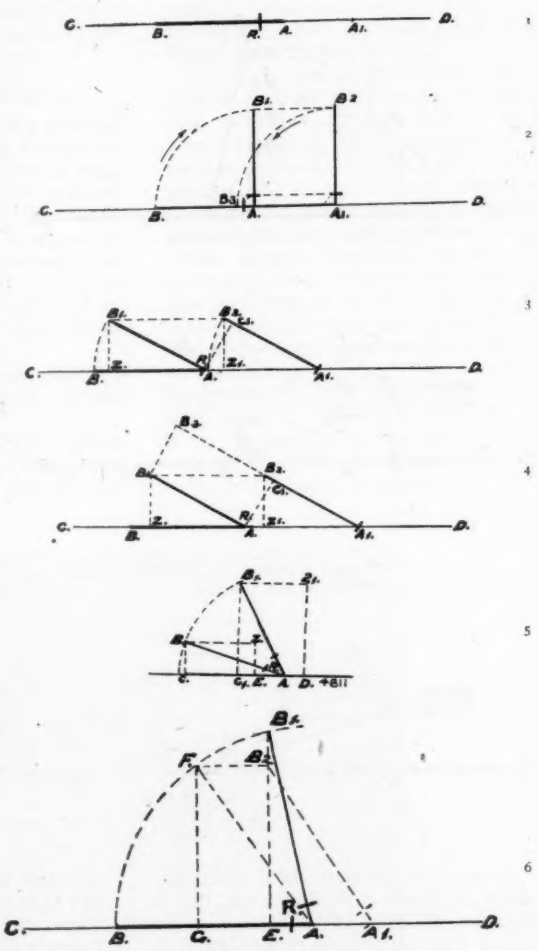
Let AB (Fig. 6) be the tracing arm, with the roller at R. Describe any arc BB_1, with the tracer B from A as centre. From B_1 move the tracer vertically downwards till it meets line CD at E. Then the roller will have recorded the area of the semi-segment, BB_1E.

When the tracer has reached any point B_2, on the line B_1E, draw a line, B_2F, parallel to the line CD, till it meets the arc BB_1. When the tracer is at B_2, the centre A has necessarily travelled a certain distance, AA_1, towards D.

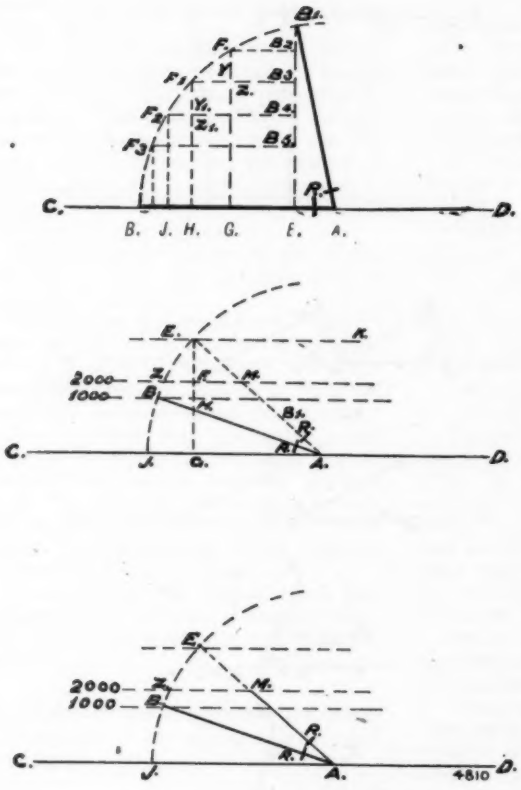
To find the distance AA_1, join A to F, and A_1 to B_2. From F drop a perpendicular, FG, on the line CD. $FG = B_2E$ (being opposite sides of rectangular parallelogram $FGEB_2$ by construction), and $FA = B_2A_1$ (being tracing arm).

$\therefore$ FGA and B_2EA_1 are two right-angled triangles with perpendiculars FG and B_2E equal, and hypotenuses FA and B_2A_1 equal.

$\therefore$ Base GA = base EA_1 (deduction from Euclid I. 47).



FIGS. 1 TO 6.



FIGS. 7 TO 9.

From each of these take away EA, which is common to both, and the remainders, EG and AA_1, are equal. But $GE = FB_2$ (rectangular parallelogram by construction).

$\therefore FB_2 = AA_1$.

$\therefore$ When tracer has moved down a vertical distance, B_1B_2 the centre of the tracing arm has moved a horizontal distance, $AA_1 = B_2F$, and in moving the tracer from B_1 to B_2 the tracing arm has passed through identical angles to what it passed through when the tracer moved round the arc FB_1.

$\therefore$ The movement of the roller caused by the *angular* movement of tracing arm has destroyed itself (see Case II). The roller will therefore have recorded an area equal to length B_2F, which equals GE, multiplied by a perpetually decreasing height, as the tracer descends from B_1 to B_2, and consequently the angle of tracing arm, relative to CD, also decreases. The area recorded will thus be that of fig. GFB_1E.

Look at this in another way. Consider line GF to approach infinitely closely to line B_1E, the figure GFB_1E will become a rectangle of infinitely small width. The whole area of the original figure, GFB_1E, may be thus considered as composed of an infinite number of rectangles of infinitely small width, but of perpetually decreasing height; the heights being recorded on the index roller by the change of angle of tracing arm, and the numbers by the travel of the roller.

Similarly by drawing lines B_2F_2, B_4F_4 etc. (Fig. 7), parallel to CD, on moving the tracer from B_2 to B_3 the roller will record area HF_1FG; on moving tracer from B_3 to B_4 the area recorded will be that of figure JF_2F_1H, and so on till the horizontal line is reached, when the complete area of the semi-segment will be recorded.

By exactly similar reasoning the area of an irregular figure can be shown to be correctly recorded on the index roller, so long as the tracer is returned to the zero line.

In the case of any figure coming wholly above the zero line, the tracer must be returned to the starting-point to obtain correct registration. The zero line has, however, been considered throughout as bounding the figure on one side, because, in the integrating planimeter, all numerical

values attached to the various heights of lines on the diagrams evoluated, necessarily refer back to the zero line.

Theory of the Integrating Planimeter.

Now instead of the roller being attached (as previously) direct to the tracing-arm let it assume some other position or angle as at AB_1 (Fig. 8), in which it is shown as a separate arm.

Let the diagram, which it is desired to integrate, *not* have an equal vertical scale, and let the distance, GH, equal say 1,000 units in a given length, and let distance, GF, equal 2,000 units in the same given length.

On the arc EJ take a point which is twice the vertical distance from CD that H is.

If, therefore, on an ordinary planimeter, the tracer E, on the tracing arm AE, were moved a given length along EK, it would register 2,000 units, where tracer B on tracing-arm AB over an equal length would register 1,000 units.

Now let the planimeter-arm AR be fixed at such an angle to the tracing-arm AB that when tracer B is at B (or the 1,000 unit line) the planimeter-arm AR coincides with tracing-arm AB, it will then register, as in an ordinary planimeter, 1,000 units per given length. When, however, the tracer B arrives at Z (or the 2,000 *numerical* unit-line) let the planimeter-arm, and therefore the axis of the planimeter, point to E, or the scaleable 2,000 unit-line, and the roller will obviously then record over a given distance, 2,000 units, exactly as if the axis of the planimeter-arm and roller were actually extended till it reached E and AE where a tracing-arm (as in the ordinary planimeter) and E were the tracing point.

Instead of using a separate arm for the

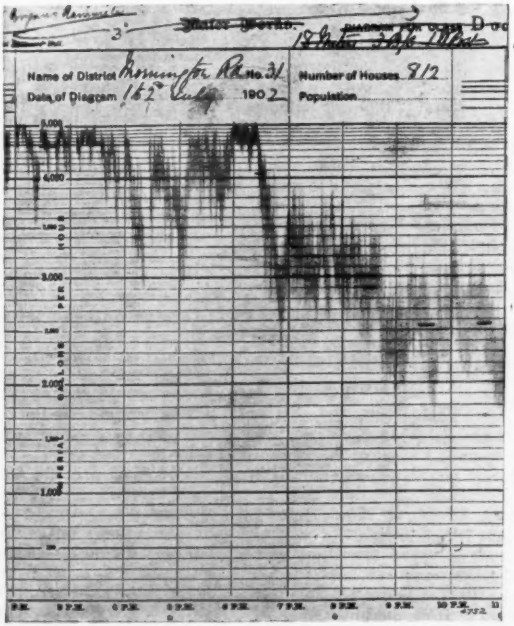


DIAGRAM FROM A RECORDING WATERMETER.

planimeter roller, it could be attached rigidly to a tracing arm, as in the ordinary planimeter, and the angularity of the tracing arm itself could be falsified by shortening it by means of a cam. For let the tracing arm AB (Fig. 9) be so shortened when it reaches angle JAE as to be of length AM, the tracing point B will in this case only reach to M on the horizontal line ZM (numerical 2,000 unit line), but will point to E (on 2,000 unit scaleable line), and accordingly the roller will record the 2,000 units correctly. The practical objection to the latter arrangement is the considerable shortening of tracing arm, and the consequent large size of cam necessary.

In either of these two latter cases (referring to the special integrating planimeter), it is obvious that the proofs given of the theory of an ordinary planimeter hold good; for the planimeter arm and roller correspond to the tracing arm and roller, as they always point to the correct natural angle, that the ordinary planimeter tracing arm and axis of roller would assume, were the scale made an equal one.

It is also obvious that a cam can be made to move the planimeter arm through, and to correct natural recording angles for any diagram, however unevenly it may be divided for equal numerical quantities.

NOTES ON LOCOMOTIVE AND RAILWAY ENGINEERING.

The writer of the following Notes—the continuation of which as a permanent feature of FEILDEN'S MAGAZINE has been decided upon and duly announced by the Editor—approaches the task of presenting what it is intended shall form a general monthly résumé of the World's Progress in matters relating to locomotive and railway engineering with a great desire to render the matter selected for treatment under this heading of value to all those who, for various reasons, take a special interest in the subjects.

The manufacturer of locomotive engines and railway plant who views the matter mainly from a commercial standpoint, the designer and purchaser (either as one or as separate individuals) whose chief concern lies in the direction of the results obtained from the finished article, as well as the independent observer, represented by a large and increasing number, will all, it is hoped, find items having reference to the particular phase of the subject which most interests them, and the writer will at all times be pleased to hear from readers upon matters of general interest coming within the scope of these columns if they will communicate with him, c/o the Editor.

Position of the Steam Locomotive in 1903.

What is the position of the steam locomotive in the present year of grace? The advancement of principles which have the effect of introducing electrical power to the serious consideration of those in whom is vested the responsibility of dealing in a satisfactory manner with railway traction problems under modern conditions, has brought to the fore a question which, as time proceeds, will require the most careful concentration of thought in order that the constantly increasing demands for improved facilities of conveyance, and the measures adopted to cope with these demands may be developed in due proportion to one another.

The arguments advanced by some in favour of electrical equipment show at the outset that the points at issue have not been properly appreciated by them, and that some of the most salient features bearing upon the subject have for one reason or another been entirely overlooked. At the same time it would be idle to ignore for a moment the utterances of competent authorities, or to blind one's eyes to facts which may be legitimately urged by those who, on account of their having made a special study of the electrical side of the question, are entitled to express their opinions, and to look for the respect and attention which is due to them.

No one can reasonably doubt that, as an instrument for providing the necessary motive power for working long-distance and "through" railway traffic the steam locomotive has still before it a lengthy career of usefulness, whatever may transpire with regard to local and subterranean lines within the next few years, for, until such time as the cost of electrical equipment and maintenance can be brought down to a figure approximating to that involved under present conditions, the existing mode will continue to be employed on the ground of lesser expense alone, without reference to other considerations.

Possibilities of Further Development.

It is frequently pointed out by the partisans of electrical operation that the stages to which the railway Locomotive in its present form may be developed are strictly governed by the limitations of the existing loading gauge, which in the case of Great Britain is none too liberal, as the majority of locomotive engineers know to their cost. Finality we are told has practically been reached in some of the latest designs, and we are asked in what direction it is proposed to seek for augmented power whilst adhering to present methods and retaining the same general outline which has done duty for so long.

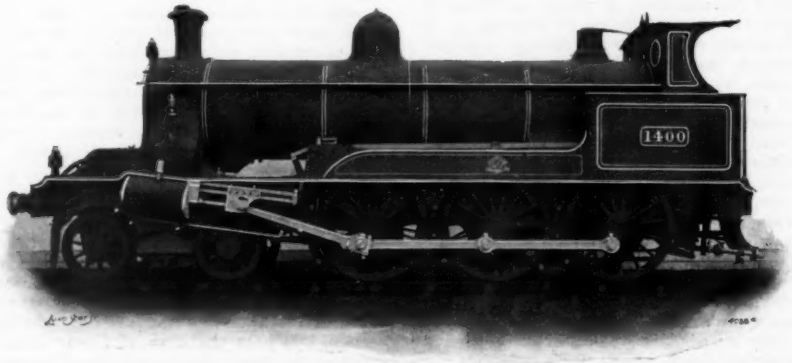
This, of course, is really the crux of the whole question. Wherein lies the solution of the "increased power" problem? There are at present two separate and distinct classes of locomotive in daily use in Great Britain, which represent, so far as actual overall dimensions are concerned, the highest stage of development possible in this country. To enlarge them would be to render their use impracticable upon any of the home railways. But do these engines represent the utmost attainable limit of power? Are they to be regarded as the "ultimatum" in this respect? That is the point which we have to consider. And the train of thought involved in such a study brings us at once to a review of the circumstances in detail; of the expedients which are being employed, and those which still remain to be tried. It is not so much that the elements for producing the necessary amount of power cannot be applied within the limits which are available, as that the capability of exerting that power, of which the design is theoretically in possession, may be taken full advantage of, with the minimum of waste occurring and the maximum of effort forthcoming when and where it is most required.

The basis of such a discussion must necessarily be found in the subject of steam itself, how to provide it in sufficient quantities, and, having once accomplished that, how to best arrange for the extraction of the highest possible percentage of its value. By an almost natural channel of thought we arrive at the complex question of compounding, and at once recognise at the very threshold of the debate the multitudinous issues which have to be taken into account.

Compound Locomotives in Great Britain.

It is passing strange that in Great Britain, which can justly claim to be considered as the "birthplace of the locomotive," this all-important matter should have met with such a comparatively small degree of popularity. It cannot be said that a proper amount of attention has not been given to the subject nor that the principles which underlie its composition are not sufficiently understood by locomotive engineers in this country. Knowledge of these facts renders it all the more difficult to appreciate the true reason for the state of affairs which exists.

If this unpopularity were of a universal character, the idea of compounding might be dismissed as belonging to that class of project, in the development of which, practice has falsified theory to such an extent that only one result could be expected, viz. the abandonment of a notion which had been proved as wrong. But compound locomotives do *not* stand in that light, either in this country or elsewhere. Mr. F. W. Webb—whose retirement from the position of chief mechanical superintendent of the London & North-Western Railway after thirty-two years of service in that capacity, took place, as is known, on July 1st—commenced opera-



LONDON AND NORTH-WESTERN RAILWAY. MR. WEBB'S LATEST TYPE 5-FT. SIX-COUPLED-COMPOUND EXPRESS GOODS ENGINE.

Cylinders	H.P. (2)	... ...	15 ins.	
	L.P. (2)	... ...	20½ ins.	
Piston stroke	... ...		24 ins.	
Coupled wheels, diameter	...	(on tread)	5 ft. 3 ins.	
Boiler diameter (mean)	... ...		4 ft. 6⅞ ins.	
Boiler, length of barrel	... ...		15 ft. 6 ins.	
Working steam pressure	...	per sq. in.,	200 lbs.	
Total heating surface	... ...		1,753 sq. ft.	
Total weight in working order (with tender)			91 tons 12 cwt.	

tions in the field of compounding as far back as 1882, and he maintained a steady rate of development and material progress during the twenty intervening years. The engines of his design are among the most successful of any in the British Isles, and they are constantly being called upon to perform some of the hardest work in the country—a duty which they, especially the latest four-cylinder classes, are discharging to the general satisfaction of all concerned. The latest type which Mr. Webb designed, and the first of which (No. 1400, turned out of Crewe works in March of the present year) is illustrated herewith, represents a unique class of engine so far as this country is in question.

The presence of such features as three pairs of coupled wheels, a leading four-wheel truck, and four cylinders in the same design is not to be found on any other British railway, although the type is by no means uncommon abroad. Engine No. 1400 was designed and built with remarkable despatch, even for Crewe works—the almost unlimited resources of which must be seen to be appreciated. The system of interchangeability of parts and uniformity of standards, in which Mr. Webb is such a strong believer, contributed principally to the rapidity with which the design was worked out and the engine built. The cylinders, valves, and motion are identical with those used in the 4-ft. 3-in. four-cylinder goods locomotives. The boiler is of the same size and construction as those of the same engines, and the coupled wheels of the new class and those of the previous 18-inch goods engines are cast from the same pattern. The natural outcome of this system is a great saving both in time and initial expense.

The writer will follow with especial interest the working results obtained with these locomotives, having been privileged by Mr. Webb to examine the pioneer engine both during construction and after completion.

A distinct class of traffic exists upon the London & North-Western Railway for the new locomotives to perform, and there can be little doubt that they will be found to supply a want which has been felt during recent years upon the railway for which they have been constructed.

Mr. Johnson's compound locomotives, built upon the "Smith" three-cylinder system, are, if all reports are to be relied upon, doing wonderful work upon the Northern sections of the Midland railway, and it will come as a great surprise to the majority of those who make a study of these matters, if the two examples at present constituting the series are not followed by a number more of similar description.

Thus we have, on two of the most important railway systems in the kingdom, compound locomotives which are proving themselves efficient and capable machines, and when it is further remembered that they were designed by two of the ablest and most prominent of British locomotive engineers, it is a matter of the greatest wonder that no sign of others following suit is being manifested at the present time.

The Position Abroad.

The outlook, so far as foreign countries are concerned in respect of this branch of the subject, is precisely the opposite.

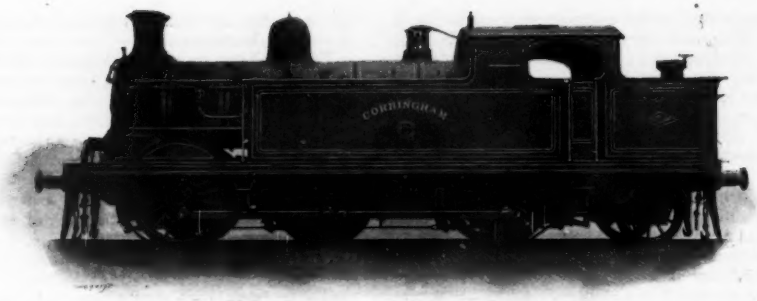
On the European Continent, the compound locomotive is predominant in every sense of the word. Engines with high-pressure cylinders only, such as are almost universally employed in this country, are, in the vast majority of instances, rapidly going out of vogue on the other side of the English Channel.

The introduction of the celebrated "De Glehn" compound system is mainly responsible for this. Perhaps no such absolute reversal of previous methods has ever taken place before with regard to engineering standards as was brought about by the introduction of M. De Glehn's system, when French locomotive practice was practically revolutionised, and the general trend of Continental opinion in these matters completely altered.

It is now common knowledge that this system, which has met with such remarkable success on the Continent, is to be tried in this country, an event which will—through the medium of the Great Western Railway Company, for whom one of these compound locomotives is being constructed in France at the present time—demonstrate once and for all whether or not the methods which have proved so uniformly successful abroad can be equally well applied in the case of British railways under the conditions which govern the conduct of their traffic; and if this turns out to be the case, as it is expected to do, it goes almost without saying that the impetus which is so much needed to bring locomotive compounding in this country to a standard approximating to that which obtains elsewhere will be forthcoming, and the whole question settled upon the basis of exhaustive experiment and research.

Efforts in Other Directions.

But while British locomotive engineering, taken upon the whole, is behindhand with



LONDON, TILBURY, AND SOUTHEND RAILWAY. EXPRESS TANK ENGINE RECENTLY COMPLETED BY THE N.B. LOCOMOTIVE CO., GLASGOW.

Cylinders, diameter	... ...	18 ins.	
Piston stroke	... ...	26 ins.	
Coupled wheels, diameter	... ...	5 ft. 3 ins.	
Boiler diameter (mean)	... ...	4 ft. 6 ins.	
Number of tubes	... ...	201	
Diameter of tubes	... ...	1⅞ in.	
Total heating surface	... .	1,046 sq. ft.	
Total weight in working order	... ..	64 tons 13 cwt.	

regard to the development of the compound locomotive, it is in the very front rank in every other respect. The prejudice against adopting any features which could be identified with foreign practice which dominated the councils of motive-power engineers in this country for so long has given way during recent years to the more enlightened policy of embodying such characteristics as have proved successful abroad in the designs which are found to be most suitable here.

The conservatism thus discarded has never occupied a prominent position in the proceedings of foreign engineers, so that the measures now being adopted on this side only partake of the nature of reciprocal action, from the adoption of which nothing but good results may, generally speaking, be anticipated.

This new tendency is not confined to the consideration of details only. Locomotive types which were, until recent years, unknown to British railways so far as actual working of them is concerned, are becoming comparatively common at the present time. Among these types, those bearing such distinctly American titles as the "Atlantic" and "Decapod" (or ten wheels coupled type) are the most prominent, whilst the special constructional details copied from abroad are represented by the extended smoke boxes, separate saddle-pieces, and chimney deflector caps, which are now coming into use in this country.

All this does not go to demonstrate that it has become necessary to look abroad for that which is best in locomotive design, and at a later stage it will be shown in these notes to what an extent the improvements in the practice of other countries is due to the tendency manifested by foreign engineers to imitate their professional brethren in Great Britain.

Atlantic Type Locomotives on the East Coast Railways.

It would seem pretty evident by this time that both Mr. Ivatt of the Great Northern Railway and Mr. Wilson Worsdell of the North Eastern Railway have arrived at a definite opinion as to the merits of the Atlantic type of locomotive. The new accelerated timings, which came into force on July 1st on the East Coast route to Scotland, entail locomotive work of a very arduous description, involving as they do long runs without any intermediate stop at continuously high rates of speed. On the Leeds service of the Great Northern Co. a still longer non-stop run is being performed than in the case of the Scotch trains. The distance between Wakefield and London, 175¾ mls., is being covered in 3 hrs. and 10 mins., which represents extremely hard going—with the loads hauled—on the part of the locomotives employed. The Great Northern "990" class of ten-wheel express locomotive are taking their share in this work, whilst Mr. Worsdell's monster "Atlantic" type engine will be put in service on the through accelerated trains when it is complete and in proper running condition, so that it will be quite possible before long to travel right through the whole distance from London (King's Cross) to Edinburgh (Waverley) behind Atlantic type locomotives. If at any time it should so happen that the Great Northern engine, No. 271, which has

15 ins. by 20 ins. cylinders and the new North Eastern engine with 20 ins. by 28 ins. cylinders should be consecutively employed on the through train on the same occasion it would be somewhat in the nature of a coincidence that the locomotive having *the* shortest piston stroke of any express engine in this country, and that with the longest (with one exception) would be engaged in dealing with the same train under remarkably similar conditions on the same day, so that an interesting comparison of working results would be rendered possible.

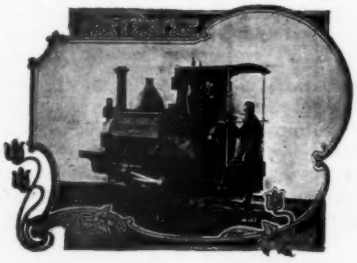
New Engines for the Tilbury Line.

The North British Locomotive Company have recently completed at their Glasgow works some tank engines for the London, Tilbury and Southend Railway. These are of two different designs, one of which is entirely new to the line in question. The morning and evening "business" traffic, particularly between London and Southend, and *vice versâ*, is very heavy, especially during the summer months, and necessitates the use of powerful locomotives in order that it may be satisfactorily dealt with. It has been the practice for some time past to employ two locomotives on the 7.44 a.m. up-train from Southend, which runs from Leigh to Barking, a distance of 25¼ mls., without a stop at a very creditable rate of speed. At the latter station the pilot engine is detached, and the other is left to work the train into Fenchurch Street without assistance, a by no means easy task in view of the weight of the train, the obstacle presented by the adverse gradient of 1 in 100 at Bromley, and the exigencies of traffic in the London district.

The engines of the class illustrated would be admirably suited to the performance of such work as that represented above, owing to the greater tractive power possessed by them, whilst they should also be capable of developing all the speed qualities which are called for under the circumstances.

The same builders also have in hand at the present time an order for twenty-five heavy eight-coupled tank locomotives, with leading bogies and "radial" trailing wheels. These are intended for the Natal Government Railways, and will weigh when complete 54 tons each. This design will be illustrated in a future issue.

CHARLES S. LAKE.



Case-Hardening.

Of all the practical metallurgical processes carried on in the works of iron and steel users, one of the most important (if not the most important) and most difficult to perform properly is that of case-hardening—*i.e.* the partial conversion of iron into steel, or the semi-conversion of mild steel into steel of a much harder and closer grained variety.

If an iron or a steel containing a low percentage of carbon be heated to bright redness in contact with a substance rich in carbon without access of air, the iron will be impregnated with carbon, the depth to which the carbon enters depending on many things, the principal being the time allowed for the operation, the quality of the material, and the *temperature at which the operation is carried out.* The importance of this last statement cannot be over-emphasised, for on it depends the success or total failure of the process. The writer has had the opportunity during the last few years of examining hundreds of specimens case-hardened at many different temperatures, and the difference of the results noted are worthy of special mention. In some cases the piece had only a slightly perceptible grain, in others the grain was coarse and uneven, while yet, in a third, the fracture exhibited was uniform in appearance and of a fine grey colour. The variation in depth to which the carbon had "struck" was remarkable: in several no difference was noticeable, in others a skin about $\frac{1}{16}$ of an inch had been gone through, and in extreme cases as much as $\frac{5}{16}$ of an inch was recorded.

There are a number of ways in vogue in the works for carrying out the process, the method decided upon usually depending upon the nature of the work in hand, and the degree of hardness required. In all cases, the piece must be completely machined before being case-hardened, being ground to size afterwards if required.

One way is to heat the work to redness carefully (turning it round during "the heat" to ensure the whole piece being at an even temperature) in a smith's fire with the blast turned low, and, while at this heat, rubbing it over with a mixture of equal parts of prussiate of potash (briefly potash) and common salt. The salt plays no part in the re-action, but merely acts as a flux, reducing the melting point. The piece is now said to be "carbonised," and to harden we have to plunge it into a trough of cold water or oil. Quenching in oil makes the steel much tougher but less hard. If the work is small and of delicate nature, it may be protected by inserting it into a short length of pipe previously placed in the fire.

The writer is acquainted with an engineer who, more than twenty years ago, used a modification of this process for all the motion work of some French locomotives. The piece to be case-hardened was heated to redness, and quickly plunged into a molten bath of potash and salt, and kept there for a time varying with the size of the piece, afterwards being quenched in an oil bath. In some cases the potash had struck to a depth of $\frac{1}{4}$ of an inch. The gear case-hardened in this manner is still in use, and shows little sign of wear, and the writer begs to offer this in defence of a process which is oft-times passed over lightly by engineers as unsuitable. The piece on which the operation is thus performed is seldom spoken of as "case-hardened," it is usually termed "potashed."

By far the most common method is to place the pieces in an iron case in company with either bone-ash, leather, or horn cuttings. The hydro-carbonated bone-black made by a Liverpool firm gives excellent results in practice. Though being more costly in the first instance, the high quality and depth of the steel case amply repays for the extra initial cost. The bone-black is made by charring good hard white bone (free from grease) in closed retorts, and whilst hot impregnating

with carbon extracted from a pure hydrocarbon oil. It is said to possess three times the case-hardening power of the ordinary forms of bone-black. Taking care that no two pieces are in contact, and carefully luting all the joints between the lid and sides of the box with fireclay or loam, to exclude the air, and heating to redness in a furnace for a time varying with the number and size of the pieces, many of the leading locomotive makers in England and America use an oil or gas furnace, and they claim several advantages for them over the ordinary type: the temperature can be regulated to a greater nicety, it is cleanly in use and more economical than the coal or coke furnace. It is not improbable that in the near future a furnace utilising electric energy for generating heat will be introduced.

A good plan is to put the box in to heat at 5 p.m., and allow it to remain in the furnace till 6 a.m. next morning, or as much after as is thought necessary. A practical man can usually tell at a glance the proper length of time required for any box, and also when the right temperature has been attained. The boxes are then broken open, and the pieces thus "carbonised" are immediately plunged into cold water, moving them about the while to be certain of an even rate of cooling. If a piece be of uneven thickness (which is usually the case), the thicker part is always put in first, so cooling the exterior, the heat from the interior tending to equilibrate the effect produced by the sudden cooling on the piece being totally submerged. An alternative plan, which is usually adopted in the case of all the gear connected with motion work, is to "potash" the pieces after removal from the boxes before cooling them. This process is the one usually termed "case-hardening" in the works, for it is desirable to discriminate between the two.

It is as well to mention here that bone-ash is the cheapest, as it can be used over and over again by adding new bone to the mass and mixing thoroughly each time a box is charged. The size and shape of these boxes depends largely upon the class of work in hand, but a good arrangement (in the case of cylindrical boxes) is to build them up in sections, and fasten them together by three or four bolts. Boxes made in this manner can be altered in size at will, which greatly reduces the initial cost of plant when a large variety of work is passing through. The cooling tanks are usually fitted with perforated trays, to accommodate as large a number of pieces as possible to the best advantage.

In order to get some idea of the case-hardened state of the pieces in a box, it is usual to take three test specimens (say 9 ins. by 2 ins. by $\frac{3}{4}$ in.) and case-harden them with the pieces. These are broken and the state of the specimen is noted, and if found satisfactory the work is passed. The disposition of these test pieces in the box is of vital importance, as the box is by no means certain to be at a uniform temperature; and this is often noticeable on opening it out and noting the condition of the various parts. The testing pieces (previously brightened) are usually placed in the centre of the box in such a position that they may be withdrawn from the box through plugged holes in the lid, either by a piece of iron-wire attached to them, or they may be made long enough to project through the lid, in which case they can be pulled out with a pair of smith's tongs.

The distribution of the test pieces is also worthy of special mention. In one of the largest engineering works in the North the man for whom the work is being done takes one piece, the manager takes another, and the third goes into the office. These pieces are numbered and kept for a time—this same firm have all the test pieces for the past twelve years—with the fractured surface carefully protected by means of tin foil (or material of a similar character), and if the work goes wrong the test piece can be referred to. The office piece can be "scrapped" after being passed.

Case-hardening a piece is always accompanied by an increase in volume, and care and judgment should be exercised in allowing for this increase. This applies chiefly to clearance holes and pins, the hole being made over large, and the pin small; very little grinding to the pin is then necessary. For very accurate work the piece must invariably be ground with

an emery grinder, or lapped with lead. A case-hardened piece is often badly warped or twisted, and it must be brought back to its original condition by means of powerful screw clamps, at the same time repeatedly hitting it with a lead hammer to destroy the "spring."

In some cases (one end of the coupling rod of a six-coupled locomotive is an instance) one part of a piece has to be case-hardened, whilst another in the immediate vicinity has not. This may be carried out by covering the latter part with thin sheet-iron, clamping it firmly in position; or, in the example quoted, the hole is covered with a couple of iron discs, firmly bolted together by a bolt passing through the hole. Another method is to protect the part with clay or loam, but this is only successful when there is a key to hold the covering in position. Nuts are often case-hardened in this manner, the hole in the nut being filled and the faces hardened.

The hardened surface is liable to crack off, and work case-hardened carelessly at a wrong temperature is always badly pitted, which means a lot of labour for the final finishing stages, besides being indicative of bad workmanship.

H. H. BROUGHTON.

How Great Britain is meeting Foreign Competition.

V.—SCOTCH BRIDGE BUILDING. (I.)

Messrs. Alexander Findlay & Co.'s Works, Motherwell.

By G. HALLIDAY, Wh.Sch.

THE daily press have been for a long time dinning into our ears that Britain as an industrial country is decadent, and Mr. Carnegie and Mr. Stead continually tell us that it is almost useless for us to try even to compete with the United States. Recently also a paper was read before the Institute of Civil Engineers, in which we were informed of the modern methods of the Bridge Building Shops of the United States, and told that it was simply impossible to undersell them even in our own Colonies.

The discussion was improved by the Manager of Messrs. Westwood & Co., of London, who has had much experience in these matters. He pointed out that it was impossible for American firms to work satisfactorily at the price taken on recent contracts, and said that it was quite well known that they did the work at a loss simply to get it in their hands. Regarding the efficiency of the structures he gave many instances of inferior workmanship, and of broken-down American-built bridges in the Colonies.

If only people would look about them and see what is going on in this country, they would find such an examination a perfect cure for the lost-industry mania. The writer recently had the advantage of going through the workshops of Messrs. Alexander Findlay & Co., Ltd., Motherwell, near Glasgow; and had his spirit been heavy with the warnings of industrial disaster which he had read in the daily papers, what he saw would have provided an instantaneous cure.

I was first conducted into the drawing office of the firm, which is an extensive room lighted from all sides, and in which draughtsmen were working at their drawing boards on the general views and details of construction of the bridges, roofs and general constructional work they have in hand. Tiers of drawers, which held the sheets of drawings of structures erected by the firm, stood all round the room and the treasures contained in them were pulled out for me to examine. There were the drawings of the great pier to be built for the more expeditious shipment of the Spanish iron-ore at Almeria; there were the drawings of the bridges for the Imperial Railway in Northern China, these being ten in number and of very considerable span; and the drawings of the magnificent passenger station at St. John's Wood for the Great Central Railway, etc.

Large extensions were being made, while I was there, to their drawing and general offices, one special feature of these being the separation of the estimating department from the general drawing-office. The estimating is looked after by one set of draughtsmen, and the works department by an entirely independent set. There is thus no chance of any particular job being delayed in the drawing office by an inrush of estimates, a not infrequent occurrence in many shops; and it also ensures that all inquiries will be thoroughly investigated.

In the new offices have been fitted up an electric printing apparatus for the photographing of drawings, and a complete system of telephones serves to keep the heads of all departments in touch with one another.

As I left the offices and entered the principal bay of the bridge-building department, I was struck by the easy system of manipulation of the huge girders which were being constructed. There was a web-plate girder being manufactured at the time, and a description of the manner in which it was being conducted through the shops will explain the methods in general use in Scotland at the present day.

At one end of the main bay there is a siding from the Caledonian Railway Company, on which all the raw material is taken into the works on wagons and within reach of the discharging cranes. As soon as the material enters the shops the manipulation begins, and it shows how carefully the position of the various machines and departments have been arranged, when I was told that no job ever required to come back to the shop: its progress is always one way from the time it

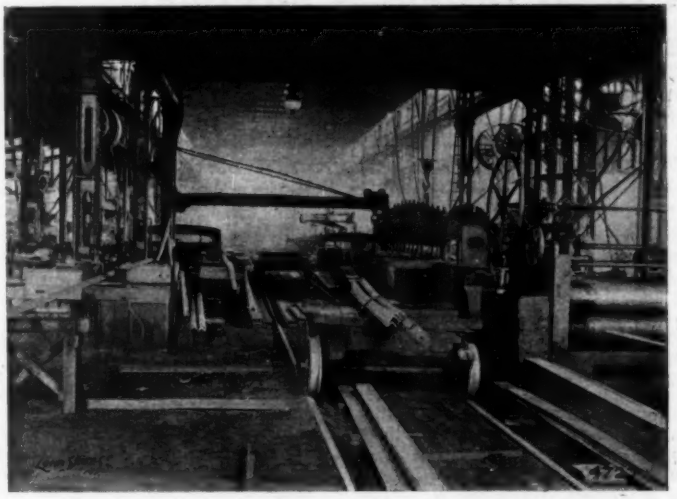


FIG. 1.—MAIN BRIDGE SHOP.

FIG. 2.—GROUP OF DRILLING MACHINES.

enters as plates and bars until it leaves as a finished article at the opposite end. As the raw material is being discharged from the railway wagons, it is all carefully checked and allocated, and sent into the shops by the yardsmen to the particular machine just as required.

The first machine on entering the shops is the large plate-straightening mill, capable of flattening plates 72 ins. wide from $\frac{3}{16}$ in. to 1 in. thick, and through which all plates pass.

Abreast of the straightening mills are the machines for straightening angles, channels, or flats, etc., each machine being fitted with a double hammer, so that the operator can either set or straighten two different sections of bars at the same time. After leaving the straightening machines, the bars are marked for drilling and sawing.

The saws, of which there are six in constant use, have a slow movement, and are not like some which cut the iron in a heated state. They are circular, fairly wide in the cutting teeth, and to keep them from becoming overheated water is run on the face. These saws cut through the bars at the rate of about $1\frac{1}{2}$ in. per minute.

With regard to the girder stiffeners, there is in use a complete set of hydraulic blocks for making the necessary "sets" at the top and foot of each, in this way dispensing with a considerable amount of expensive smithwork, which, previous to the adoption of this hydraulic pressing, was entailed in the the making of these stiffening bars.

Fig. 1 is a view in the main bridge-shop which shows the large straightening rollers, and beyond them the long plate-edge and plate-end planer. The latter is capable of taking plates in to a length of 30 ft. Cranes for lifting these plates on and off the machines are fitted against each alternate pillar, and they are made with sufficient arm-

FIG. 3.—WARREN GIRDER BRIDGE FOR THE CHINA IMPERIAL RAILWAY IN COURSE OF CONSTRUCTION.

length to command every part of the shop. Rails are also laid along the floor, so that the angles and plates may be wheeled in bogies to the places at which they are wanted. Then there are the drilling machines in three rows, as shown in Fig. 2, lighted at night by electric lamps suspended above them. The central row containing 20 machines at 6 ft. centres, can take in a girder 120 ft. long and finish both flange and web holes at one placing. To insure perfect coincidence of the holes in the parts which are brought together, a bunch of plates are fastened together and drilled through at the same time from one used as a template. By adopting this method there is not the least difficulty in getting the

FIG. 4.—BRIDGE TO CARRY ROAD OVER THE TINA RIVER, SOUTH AFRICA.

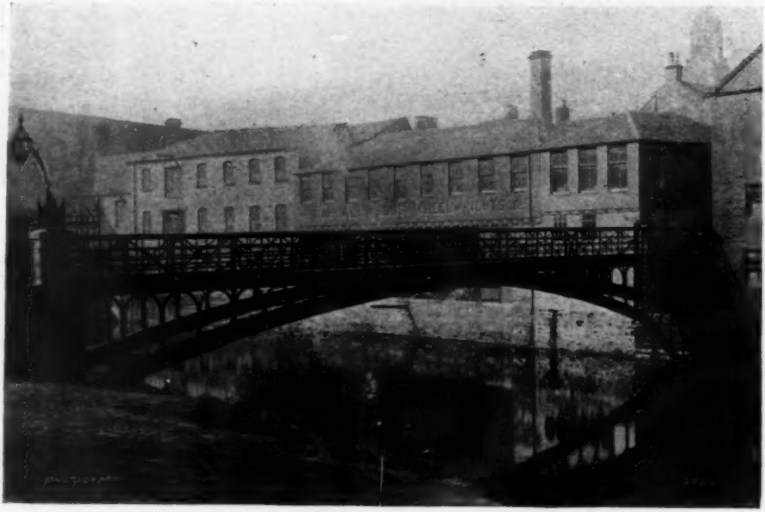


FIG. 5.—RIVER BRIDGE NEAR KILMARNOCK.

holes in opposite plates to coincide and the rivet goes easily through them both.

After leaving the drills the various parts are taken asunder to allow of all burrs, etc., being removed and the layers have a coat of hot boiled linseed oil before being tightly bolted together and handed over to the riveters. The riveting machines, both hydraulic and pneumatic, number about a dozen, and, in ordinary work, two men and two boys can clench over 1,500 rivets per day. Particular care is taken as to the formation and line of all riveting done. Furnaces arranged with forced draught and fixed at suitable places are employed to heat the rivets, a boy attending to this heating and handing them out with tongs as required by the riveter. The two men manipulate the hydraulic riveter and rivets are put in place for them by the other boy. The speed at which these four persons drive home the rivets is marvellous, three days sufficing to rivet up a huge girder 60 ft. in length by 6 ft. deep.

All sorts and sizes of these girders are constructed, but the usual plate type is perhaps the most common. One in course of construction was 64 ft. in length and 5 ft. in depth, with flanges 20 ins. in breadth, and it weighed 22 tons. The men have become so accustomed to the work that only from eight to ten days are necessary to construct and finish such a girder after the material has been delivered in the yard.

We come to another kind of bridge built by the same company, viz.: the warren type. Those shown in Fig. 3 are huge substantial girders constructed for the bridges of the Imperial Railway of North China. Each span consists of two main girders 106 ft. in length by 13 ft. 9 ins. deep with box-section booms. Each weighs about 32 tons. There are nine cross-girders in each span, 29 ft. in length and 3 ft. in depth, for carrying the floor. These cross-girders are of the single-web type and each weighs about 3¼ tons. They rest on the bottom booms of the main girders. Between each pair of cross-girders there are four rail bearers, 13 ft. in length by 2 ft. deep, of single-web type, and each weighs about 12 cwts. Each pair of rail-supporting girders are strongly braced together at the centre. The total weight of each bridge 100-ft. span is about 120 tons, and ten bridges have been built for the railway.

The Fig. 6 shows one of the main girders at Birkwood Burn Viaduct on the Caledonian Railway's new Mid-Lanark and Ayrshire lines in process of erection. The girder is 92 ft. 8 ins. in length and 22 tons in weight. The steel-work required for this extension was very considerable, as altogether there were over 70 steel bridges; included in which were three viaducts of three spans each, one of four spans and one of six spans. Those bridges required for the viaducts were all of the same type as the one shown at Birkwood: 36 main girders were required for the five viaducts and each was about 93 ft. in length and weighed about 22 tons. On the same line were two large viaducts of eight 56-ft. spans each, and one viaduct of eleven spans of 66 ft. each, and the girders were of the web-plate type.

We have only space to take typical bridges. Railway bridges of the girder type do not appear very beautiful to many who are not engineers. These will admire more readily the arched form of the foot-bridge, as for instance that over the river near Kilmarnock, which we show in Fig. 5. As will be seen, the bridge is carried by two arched ribs placed 10 ft. apart with 90 ft. clear span and are 1 ft. 6 ins. deep. The rise at the centre is 7 ft. 6 ins. The trough flooring is 6 ins. deep and rests on the top of the rib at the centre. The space between the flooring and the rib from the middle to the ends is filled in with arched T-bars. The parapet is 4 ft. high and consists of T-bar verticals with a horizontal T-bar along the top. The spaces between the verticals are filled in with diagonal lattices, and horizontal and vertical flat bars with cast-iron ornamental stars at the intersections. The arched ribs are bedded hard against the solid stone-work at each end, to prevent them spreading and consequently sinking in the centre.

Fig. 4 shows a road bridge in progress of erection for the colony which has been so much in everyone's mouth during the last three years. The photograph shows a good view of the type of lattice-girder used and the flooring is of the "Findlay" type.* It is a road-bridge to be built over Tina River, and consists of three spans of 99 ft. 6 ins. clear. Each span is carried by two main girders of the lattice type, with double-web booms. There are ten cross-girders to each span. Each cross-girder rests on a stool placed between the webs of the bottom boom of the main girder. They are of the fish-bellied single-web type, with a depth of 1 ft. 8 ins. at the centre and 1 ft. at the ends. There is a clear width of 16 ft. between the girders, 8 ft. in the middle is allotted to vehicular traffic and the two sides arranged as footpaths each of 4 ft. in width. The middle roadway is

* A separate department has recently been added for making this flooring, and Messrs. Findlay are now in a position to stamp from one plate a trough 36 ft. long, 18 ins. deep, and ¼ in. thick. The hydraulic plant, furnace, press, and hydraulic cranes are arranged in such a manner that three men are all that is required for manipulating these large plates.

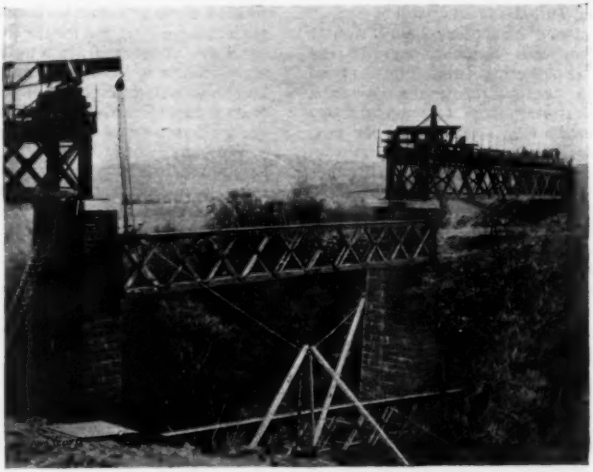


FIG. 6.—MAIN GIRDER OF A LARGE RAILWAY VIADUCT IN COURSE OF ERECTION.

FIG. 7.—THE ROOF OF MARYLEBONE STATION, LONDON, GREAT CENTRAL RAILWAY.

crossed with strong stamped-steel trough-flooring 6 ins. deep, running, as shown, longitudinally, and resting firmly on the cross girders. The footpaths are made of 3-in. planking raised up from the steel flooring by means of curb plates and angles. The main girders rest on expansion rollers at one end. The whole steelwork of the bridge weighs about 160 tons.

The view, shown in Fig. 7, of the Marylebone Station of the Great Central Railway, London, will be recognised by many. It is a magnificent structure ; and was fully described in Vol. II., page 422, of this magazine. The roofing covers an area of 300 ft. in length and 100 ft. in width, over the promenade adjacent to the station buildings, and an area of 500 ft. in length by 160 ft. in width over the platforms and cab road which runs at right angles to the promenade.

We come now to another type of structure built by this firm, which also can be inspected in London by engineers interested. It is in connection with the Greenwich Footway tunnel which runs beneath the River Thames from Greenwich to Poplar. This tunnel has two vertical shafts, one at each end, up and down which passengers using the tunnel pass by means of a spiral stair.

The shaft at the Greenwich end is 50 ft. 6ins. deep, and that at the Poplar end is 44 ft. deep. The treads of the stair are supported by stringers built of angles and plates. The inner stringers are riveted to columns built of double channels placed back to back, with flange plate on the inner side, and resting on the floor of the shaft. The columns are six in number and are stayed up by radial girders fixed to the wall, and are braced at the top. The outer stringers are supported by angle brackets bolted to the wall and by H-beams running from the columns into the wall, and these help to stay the columns. The diameter of the shafts is 32 ft. 8 ins., and the width of the stairs is about 6 ft. The stairs are divided into two by a centre hand-rail. The top of both shafts is covered with a dome which is hemispherical in shape and 43 ft. 6 ins. in diameter. This dome consists of twelve arched ribs built of angles and lattices. These ribs carry the angle purlins, the whole being covered with glass. The ribs are fixed at the top to a steel drum 9 ft. 2 ins. deep by 6 ft. in diameter, which acts also as a ventilator and is ornamented with cast-iron mouldings of neat design.

The Alquife Ore Loading Stage.

Some time ago there was considerable discussion with regard to the iron-ore mines which are the property of the Alquife Mines and Railway Co., Ltd., in the neighbourhood of Almeria, Spain. This hematite ore is brought down in the company's wagons to be loaded in ships at the terminal port of Almeria. At the present time the handling of the ore between the railway terminus and the ship is of the most primitive description. It is stored at the railway terminus, and subsequently, as occasion offers, conveyed in carts to the harbour, and thence is carried in baskets to the vessels.

It was determined lately to introduce the Canadian system of handling the ore, that is, to bring it down on to a pier; and by an arrangement of shoots let it fall directly into the vessels without either cartage or hand-labour intervening. For this purpose the Alquife Coy. determined to build an extensive pier, arranged so that every facility would be offered for the conveyance of the ore from wagons on the line to the ship's hold. The preparation of the design of this pier was put into the hands of the distinguished civil engineers, Messrs. Formans & McCall, of Glasgow, and the contractors selected to construct and build it were Messrs. Alexander Findlay & Co., Ltd., of Motherwell.

The pier and loading-stage are fitted with two rows of storage bins for the ore, one on each side of the stage. Each row consists of 20 bins, and each bin is 18 ft in length. The bottoms of the bins are inclined forward and towards their centres at just such an angle as to ensure that the ore shall slip. At the front of each bin, and at its bottom, there is an adjustable shoot for allowing the ore to run down it from the bin to the ship's hold. These shoots can be pulled up out of action or let down into the suitable position for the ore to run down by a windlass arrangement at the top of the stage.

At the shoreward end of the stage the line divides into four, so that there can be four trains on the stage at a time, two above each row of bins. The approach line to the stage begins at the Railway Terminus Depôt, and is led on an ascending gradient of 1 to 45 to the shoreward end of the stage.

Each train consists of hopper bottomed wagons, each of 15 tons capacity, specially built for the carriage of the ore. The length of each wagon is such that, when the train is placed in position on the stage, each bin under it has its corresponding wagon.

The maximum and minimum depths of water are 28 ft. and 18 ft. at the seaward and shore end of the stage respectively. The foundations, however, are being carried down to admit of a uniform depth of 28 ft., which will allow of vessels of the largest dimensions to come alongside of the stage to be laden.

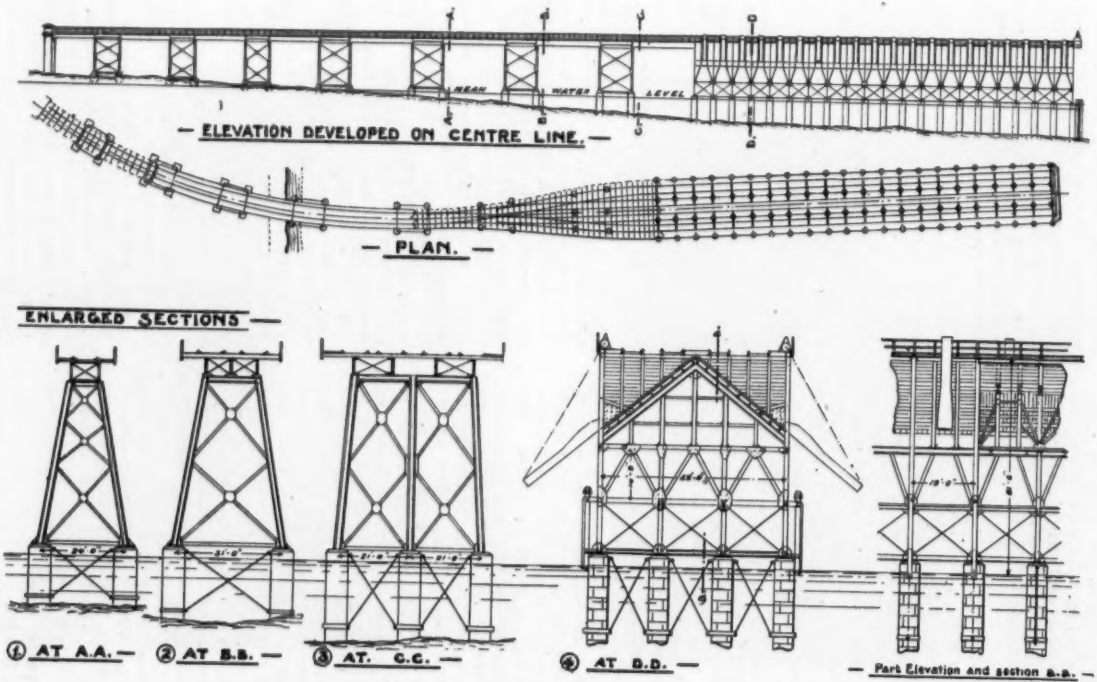


FIG. 8.—DETAILS OF ORE LOADING STAGE, ALQUIFE MINES AND RAILWAY CO., LTD., ALMERIA, SPAIN.
ENGINEERS: MESSRS. FORMANS AND MCCALL, C.E., GLASGOW.

The foundations are of concrete pillars formed in steel casings, so as to admit of their being first sunk to the requisite depth. Additional strength is given to the interior pillars of concrete by steel rails being set in them vertically and embedded in the material.

These cylindrical pillars support the stage in rows of four. These rows are spaced 18 ft. apart, to correspond with the ends of the bins. The tops of the pillars are finished about 4 ft. above water level. The superstructure is constructed of mild steel, the bins being lined with pitch pine, which is sheathed on the bottom and partly on the sides with ⅛-in. steel plates. Each bin will be capable of storing about 160 tons of ore and the whole stage will have a storage capacity of 6,400 tons of ore.

The foregoing are only a few of the types of iron girder-work made in the shops at Motherwell. They were simply noted down as the drawings were pulled out in the drawing office while the writer was there. Any of the other drawings would have served just as well to illustrate the kind of work which is constantly in hand.

The principle adopted throughout the works is chiefly that of piece-work, and on enquiry I find that the relationship existing between the firm and their employees has for years been of a most agreeable nature; and even when on time the workmen do not seem to be working on the "ca' canny" policy, of which of late we have heard so much from certain quarters.

Perhaps the point which struck the writer most was the high degree of organisation which has been reached, which was in evidence wherever one might happen to be in the works. It may be true that American workmen lead a more strenuous life and work longer hours than those in the Northern bridge-shops; but as we looked at each group and saw the work, sometimes weighing many tons, move through and leave their hands, one was forced to conclude, that, as far as highly finished work was concerned, British bridge-builders need have little fear of foreign competition.

King Edward VII. Bridge over the River Thames at Kew.

In a previous article[1] we gave some particulars relative to the history and general character of the new bridge, and we now propose to describe the methods followed in the construction of the abutments and piers, and in throwing the three arches forming the river spans. A preliminary examination of the elevations and plans of the completed structure, Plate I., Figs. 1 to 4, will probably help to explain the following notes. Before anything could be done, the demolition of the old bridge and the removal of the old piers and timber platforms were absolutely necessary. The demolition of the old structure was accomplished without difficulty, and operations were considerably expedited by the employment of an aërial cableway, of 550 ft. span, supported on trestle towers rising 60 ft. above ground level at each side of the river. The cableway was designed for a maximum working load of 6 tons, and the speed of transmission was about 12·5 ft. per second with a load of from 2 tons to 3 tons.

Although not sunk to the same depth as in the case of the new bridge, the old piers were not removed without a considerable amount of trouble. Where such a course was practicable, the core of the pier was taken out, leaving the outer shell of masonry to serve the purpose of a coffer dam, up to a certain stage in the operation, and the removal of masonry below water level was finally effected by the aid of divers. When the pier masonry had been cleared, the old timber platforms were laid bare. These were framed structures, measuring 45 ft. by 17 ft., and they were floated away by the aid of barges and chains. Altogether, six such platforms had to be removed, an operation extending from April, 1900, to November, 1901. Work was then commenced on the new bridge at the Middlesex abutment, where a coffer dam was constructed of grooved and tongued sheet piling, driven to 5 ft. below the foundation level, and rising to 5 ft. above Trinity high-water mark, as shown in the longitudinal section, Fig. 2. Between the piling the coffer-dam measured 100 ft. 6 ins. long by 77 ft. 6 ins. at the widest part, and the half-plan given in Fig. 1 shows full details of the walings and of the internal bracing and struts. A similar coffer dam was formed at the Surrey abutment, the present ground level at each side of the river being indicated in Fig. 2. When the abutment areas had been excavated, concrete was filled in, forming a foundation which, in the case of the Middlesex abutment, extends about 46 ft. back from the river line, and varies in thickness from 5 ft. at the front to 12 ft. at the back, as indicated in Plate I., Fig. 9. It will thus be seen that the foundation area is of very considerable extent, so ensuring ample provision for the distribution of weight and thrust. Fig. 7, Plate I., is a part section of the Middlesex approach, showing the tow-path arch of 18 ft. span, this being built of stone, and the remaining five arches, which are built of brick, one being of 21 ft. span, and the others of 18 ft. span. It will also be seen by the same drawing that the approach piers are of concrete, the proportions adopted being 1 to 6. Fig. 6, Plate I., gives half-sections of pier and arch No. 2, and Fig. 5, Plate I., is a section on line *AB* in Fig. 9, on the same plate, which is a complete elevation of the west wall of the Middlesex approach and abutment. Five of the arches are closed at the ends by granite walls having doorways and fan-lights, so that they may be adapted for the use of prospective tenants, and, as shown in the drawing, a flight of steps gives access to the foreshore. The Surrey approach is very similar in general construction, but there are nine arches, including the tow-path arch, and a

[1] Feilden's Magazine, July, 1903, pp. 61-63.

flight of steps leads down from the bridge to the tow-path.

After the abutments, the next foundation work to be undertaken was that for the river piers, a commencement again being made at the Middlesex side. Fig. 3 is a half plan showing two bays of the cofferdam used in building the piers, the internal dimensions of the dam being 107 ft. by 39 ft. In this case 14 ins. by 14 ins. grooved and tongued sheet piles were used, driven to 5 ft. below the finished foundation level and extending 5 ft. above Trinity high-water mark. Fig. 4 is a half-longitudinal section of the cofferdam, these illustrations showing the full details of the interior bracing and struts. It will be seen that the three lower tiers of the cross-framework consisted simply of horizontal struts, each of which measured 38 ft. by 12 ins. by 12 ins. At the centre of the span a 12-in. by 12-in. post was secured to the struts by 12-in. by 12-in. by $3\frac{1}{2}$-in. by $\frac{7}{8}$-in. angles. In each of the two upper tiers, two raking struts, a crown piece, and two $\frac{7}{8}$-in. tie bolts were added. The joints of the raking struts and crown pieces were made with cover plates, 24 ins. long by $3\frac{1}{2}$ ins. wide by $\frac{3}{4}$ in. thick, and the joints of the cross struts were covered with 18-in. by 18-in. by $3\frac{1}{2}$-in. by $\frac{3}{4}$-in. angle brackets. The whole cofferdam was strengthened by external and internal waling and vertical side-posts in each bay. In Fig. 3 the half-outline of a pier is traced, and in Figs. 4 and 5 the contour of the pier and the springings of two adjoining arches are indicated by dotted lines. Excavation was carried to a depth of about 16 ft. below the bed of the river, and, as will be seen by comparing Figs. 1 and 2, there was very little difference between the depths necessary for the Middlesex and Surrey piers. On the completion of excavation, Portland cement concrete, in the proportion of 1 to 6, was deposited to a depth of 11 ft. 9 ins, the foundations so formed having in each case the same area as the cofferdam. These dimensions have the effect of reducing the load upon the clay so that it does not exceed $2\frac{1}{2}$ tons per square foot. As shown by Fig. 1, Plate I., a curved batter has been given to the piers, the form of section so secured, combined with the extended cross-section of the cutwaters, Plate I., Fig. 8, having the effect of distributing the load over the whole foundation.

The general construction of the river piers will be sufficiently explained by the half-section in Plate I., Fig. 8, but it may be added that the facing is of coursed granite ashlar, with a solid backing of brindled brick laid in cement mortar, and that the cutwaters are provided with heavy granite caps, some of the stones weighing between four and five tons each. At the level of the concrete foundation, the piers are 28 ft. in width, decreasing to 18 ft. wide at the springing line, which passes through the centre of the tenth course, counting from the foundation upwards.

We now approach that part of our subject which relates to the construction of the three main spans. In the first place, it should be explained that the requirements of the Thames Conservancy included the maintenance of a 17-ft. headway above Trinity high-water mark, of a centre opening 75 ft. wide, and of a side opening 50 ft. wide. Therefore it was considered necessary by the engineers to make use of steel centering. This consisted of curved ribs of the form and construction illustrated in Plate II. The ribs were supported, in the case of the centre span, at the points *BA* and at two corresponding points at the other end of the span; and, in the case of the Middlesex and Surrey spans, at the points *BC*, *CB*—four supports to each span. Hence each rib formed a continuous curved girder, built up of steel plates and angles, having an average depth of 3 ft. 7 ins., and a width of 1 ft. 4 ins. Each girder was delivered in five sections, two at each end being riveted up and floated out on barges to the required positions, where they were hoisted up to their temporary supports. The centre section was afterwards hoisted into position and temporarily supported by the projecting coverplates of the side sections. The remaining coverplates were then put in place, and the jointing of the rib was completed. Plate II. shows the top and bottom plates of the flanges drawn to an exaggerated vertical scale, so that the details of construction

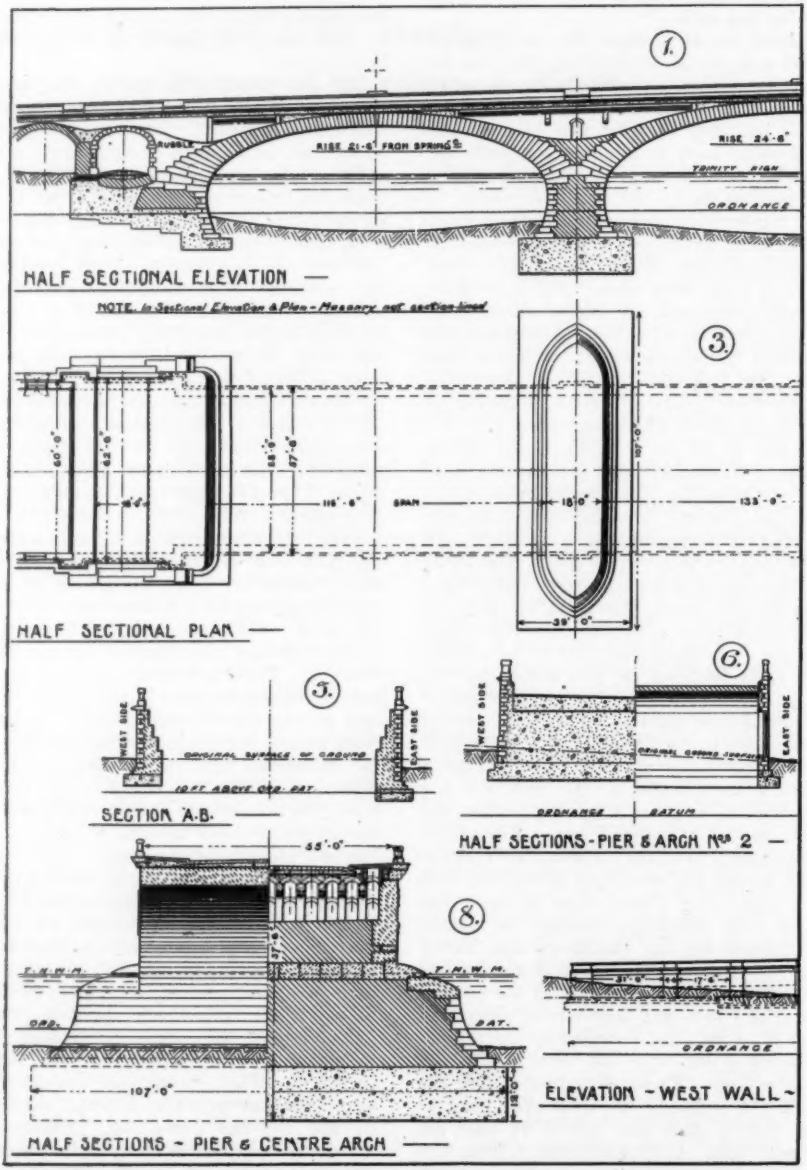


PLATE I.—KEW BRIDGE.

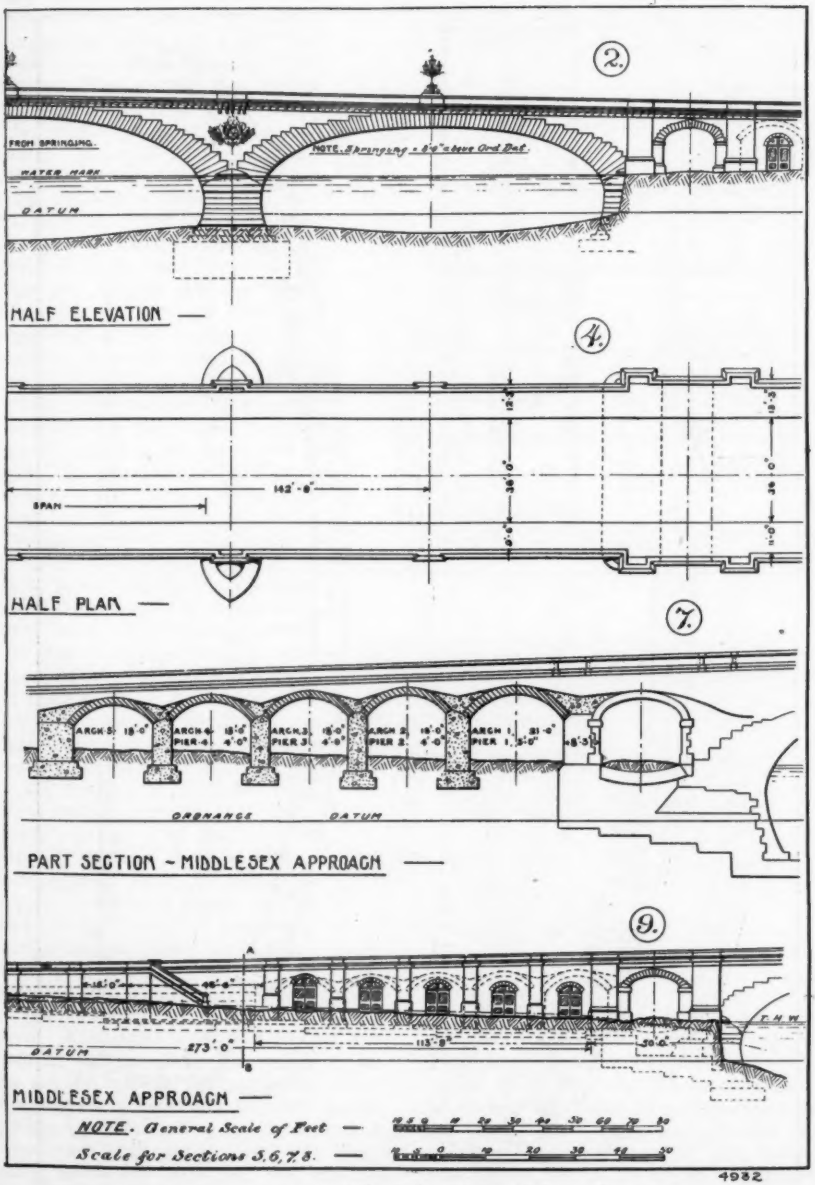


PLATE I. (CONTD.)—KEW BRIDGE.

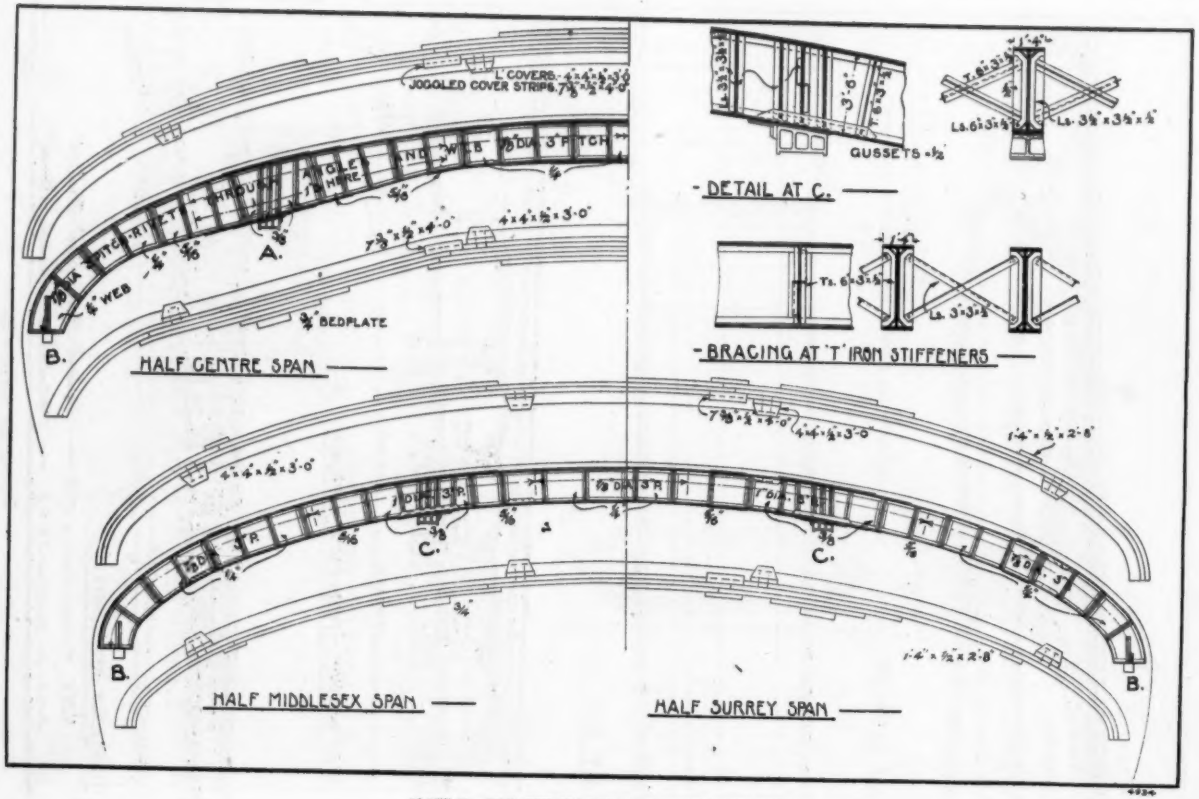


PLATE II.—KEW BRIDGE: DETAILS OF CENTERING RIBS.

may be intelligible. Eleven ribs were erected beneath each arch, the spacing being 5 ft. 7 ins. from centre to centre. Details of the bracing between the ribs at the stiffeners are also shown in Plate II. The weight of each rib for the centre span was 23 tons, and for the side spans, 16 tons. From these general observations, it will be seen that the centering practically constituted a steel arch of great strength over each of the channels formed by the piers. The ends of the steel ribs were supported at the springing of the arch by timber stooling built up on the footings of the piers and abutments. The intermediate supports consisted of two rows of piles spaced about 9 ins. apart, and in order to provide for the great weight to be carried these piles were driven fully 7 ft. below foundation level. The ends of the ribs rested upon a 14-in. by 14-in. cross timber, between which and the top timber of the stooling, hard wood wedges were inserted, one pair of wedges beneath each rib. At the intermediate points of support, *A*, in the centre span, and *C C* in the Middlesex and Surrey spans (Plate II.), cast-iron saddles, designed to give a horizontal bearing of adequate area, were bolted through the cover-plates of the ribs, and further secured by strips of plate bent to the required form, as shown in Fig. 6. Between these saddles and the top timber of the piling, wedges and sand-boxes were placed, the latter being intended for ensuring the gradual and uniform striking of the centering after completion of the arch. Each sand-box consisted of a rectangular cast-iron box, measuring 24 ins. by 16½ ins. internal dimensions by 18 ins. deep overall, and was secured to the timber by means of 1⅛-in. coach screws. The boxes were partly filled with sharp sand, on which were set the cast-iron blocks, as shown in the drawing, leaving the requisite space for insertion of the wedges, each of the latter measuring 2 ft. 6 ins. long, with a taper of 2½ ins. After final adjustment of the ribs, a 4-in. timber lining was bolted to the top flanges to correct any slight irregularities in the curvature of the centering. Across the lining a lagging of 8-in. by 4-in. timber was spiked, so as to afford continuous support for the voussoirs. No boarding

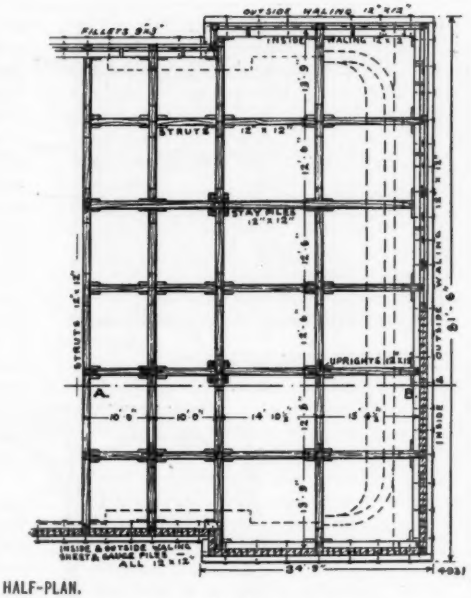


FIG. I.

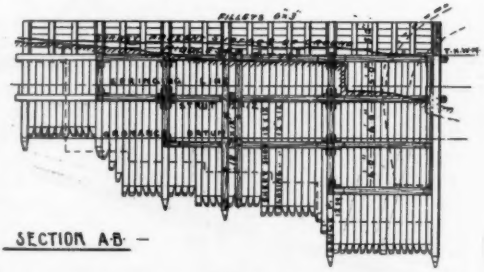


FIG. II.

KEW BRIDGE: DETAILS OF ABUTMENT COFFER-DAMS.

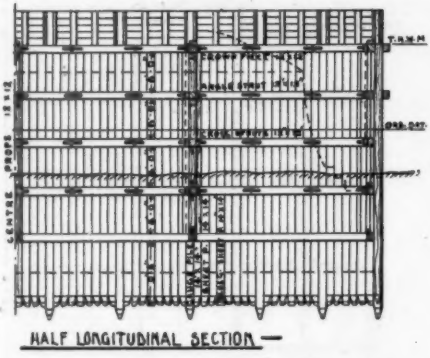


FIG. IV.

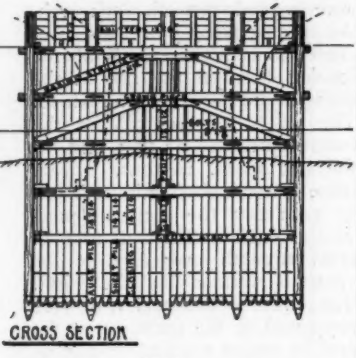


FIG. V.

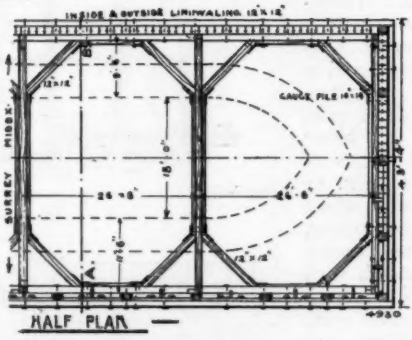


FIG III

CENTRE COFFER-DAM

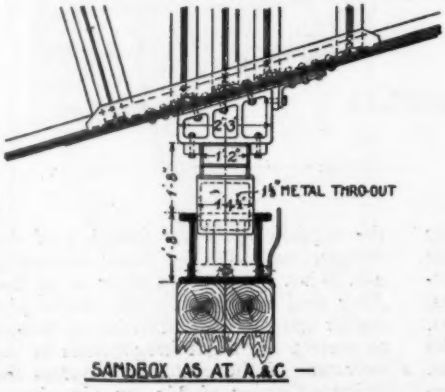


FIG. VI.

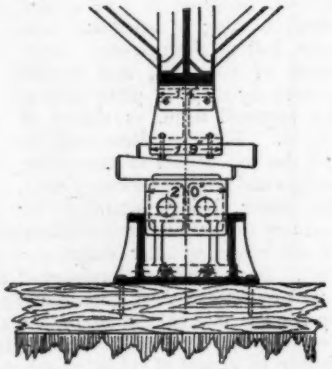


FIG. VII.

KEW BRIDGE: DETAILS OF INTERMEDIATE SUPPORTS FOR CENTERING.

was employed for this purpose, but the lagging timbers were spaced somewhat closer at the centre than at the springings and haunches. For the purpose of guarding against cracking at the joints, owing o deflection of the centering, some of the joints were left dry, and small wood wedges were inserted to maintain the proper thickness. These dry joints were afterwards filled with mortar when the arch had been completely built and the centering was ready for striking. Operations were conducted on all three arches simultaneously, this mode of procedure being necessary in order to avoid the establishment of undue or unequal strain. As mentioned in our first article, the arches are of true elliptical form. All the joints are normal to the tangent, and the springing line is 4 ft. 6 ins. below Trinity high-water mark. The voussoirs vary from 4 ft. in depth at the crown to 10 ft. deep at the springings. In laying the arch masonry the two face stones were first set, and the intervening stones were regularly laid from each face, the closure stone being near the centre of the course. The haunches of the three arches are backed with brindled brick for a height of about 13 ft. above the springing, as indicated by the hatching in Plate I., Fig. 1. Above this level we come to the spandril, with face walls of pick-dressed granite and intermediate walls of bricks 1 ft. 6 ins. thick, connected at the top by small arches 9 ins. thick, supporting the roadway, as shown in Plate I., Fig. 8. The construction of the arches was commenced about the middle of March, 1902, and completed during October in the same year. In the operation of striking the centres, which was only completed in May last, the sand-boxes were found to answer admirably, and the ribs were lowered at the rate of 1 in. in 40 minutes. When the centering was entirely clear of the arches, the lagging timbers were removed, the joints were cut and the ribs were taken away in sections. After removal of the centering, the cutting away of the piling used for intermediate support of the ribs was commenced. For obvious reasons it was inadvisable to draw these piles, and they had to be cut at such a level below the present bed of the river as to constitute no obstacle to future dredging operations. Therefore it was necessary to form trenches, which in some cases reached the depth of 10 ft, and which were often partially filled by tidal action. The method adopted for cutting the piles was to employ a saw attached to a rocking frame carried in supports from the tops of the piles.

Returning now to the final details of the bridge, we may draw attention to the handsome string-course corbelling over the arches, and to the effective treatment of the masonry work generally. The parapet is solid, and has cast-iron standards for lamps over the centre of each arch. Suitable accommodation is provided below the footpaths for pipes and other conduits, and the roadway is finished with wood pavement. About 16,000 tons of granite have been used in the erection of the bridge, Aberdeen granite being used exclusively for the parapets and for various finer parts of the work.

In concluding this brief notice we have to express our acknowledgments to the engineers of the bridge for the use of the drawings from which our illustrations were prepared, and for the particulars as to details of the work generally. **W. N. T.**

Note.—The cableway which was used in connection with the demolition of the old bridge and in the construction of the new was supplied by Messrs. J. M. Henderson & Co., Aberdeen. It had a span of 525 ft. and would easily hoist and convey a load of 4 tons at an approximate travelling speed of 600 ft. per minute, and accomplish the hoisting or lowering operations at a speed of 300 ft. per minute.

TOPICS OF THE MONTH.

The London County Council *v.* British Steel.

The Clause Proposed by the Bridges Committee.

At a meeting held during the last week of June, one more proof was afforded of the determined hostility entertained by the London County Council to British industry, an extraordinary phase of mental obliquity which is one of the few consistent attributes of this incorrigible assembly. On the occasion to which we refer, a report was presented by the Bridges Committee, in which, among other matters, some references were made to the new Vauxhall Bridge. As our readers are probably aware, it has now been finally decided that the superstructure of this bridge shall be of steel, and, in connection with the preparation of the specification, the Committee very properly proposed that a clause should be inserted, providing that all materials should be of British manufacture. It was officially stated that Mr. Fitzmaurice, the engineer to the Council, strongly supported this recommendation, pointing out that such a stipulation would enable him, through his inspectors, to exercise much better and more efficient supervision than could possibly be secured if the materials were manufactured on the Continent. It was further pointed out by the Bridges Committee that the adoption of the clause mentioned would have the effect of providing for the maintenance of the rates of wages, and of limiting the hours of labour in a manner which, it was assumed, would find favour in the eyes of the Council. The report concluded with a reminder to the effect that the general question had already come before the General Purposes Committee, and that the conclusion was then arrived at that each case should be considered on its own merits. The case in point was so considered by the Bridges Committee, and in the exercise of their discretion, which is entirely to be commended, they decided almost unanimously in favour of such a clause. Therefore, they recommended "That a clause be inserted in the specification, providing that all materials shall be of British manufacture only."

Its Rejection by the Council.

From the report before us, it appears that Mr. Henry Ward, who ought to know better, regretted very much that any clause favourable to British steel manufacturers should be inserted. He moved that the report be referred back, and his amendment was ultimately carried by a majority, which we are pleased to find was of insignificant dimensions. Considering the London County Council as a concrete body, and ignoring the evident mental efficiency of many individual members, we do not think it would be possible for anyone to have predicted, with any approach to accuracy, whether the proposal in question would be received with favour or disfavour. The Council is seldom consistent or reasonable, because it is swayed this way or that by the incurable faddists and cranks who so frequently seem to stumble into the lobby with those voting against any particularly sensible course of action. That is why it is rarely safe to reason by analogy in matters that concern the administration of London as a county. As at present constituted, the chief aims of the Council appear to be: (1) A morbid craving for increased powers; (2) An unholy desire to squander money extorted from reluctant ratepayers; (3) A thick-and-thin support of Trades' Union principles; and (4) A persistent opposition to industrial and contracting firms and corporations. Concerning these aims,

may be said that the craving for power, and the desire for spending are clearly related one to the other, and it is equally evident that adhesion to Trades' Unionism and the persecution of contracting firms conduce materially to the waste of public money. The antipathy exhibited towards industrial firms is partly due to the trade jealousy of the Council, regarded in its capacity of a municipal trading body, and partly to the rampant unreason of the Trades' Union element. Of course, we may possibly be misjudging the London County Council, but if so it is their own fault, for we are merely judging them by their own actions. Leaving out from consideration (1) and (2) as factors only remotely connected with the present discussion, we have left the questions of Trades' Unionism and antipathy of private industrial undertakings.

Inconsistency of the L.C.C. Here we find at once unmistakeable evidences of inconsistency. For if, as Trades' Unionists contend, rates of wages are to be inversely proportional to hours of work, anything that tends to limit the profits of the employer involves loss of the power to pay the higher wages desired. Hence, the prosperity of the working man is inalienably bound up with that of his employer. The London County Council, as a body, takes much grandmotherly interest in the working man. In all contract conditions, the rates of wages and the hours of labour are specified with minute care, and the dictates of Trades' Unions are followed in every respect with the most servile fidelity. As pointed out in the report of the Bridges Committee, the clause limiting the employment of steel to that of British manufacture would clearly be in harmony with the general labour policy of the Council. That the suggestion did not find favour is simply one more proof of the utter inability of that body to deal with any matter in accordance with logical principles and the dictates of common sense. It is interesting to observe the reasons brought forward by various speakers against and in favour of the recommendation.

Some Views Adverse to the Clause. Mr. W. B. Yates disliked any such restrictions being placed on the sources of supply. He contended that, if British material were cheaper, then the British manufacturer would get the contract. If it were dearer, then the London ratepayers ought not to be called upon to pay a higher price. Now, Mr. Yates is a member of the so-called "Progressive" party, and therefore, presumably, a supporter of Trades' Unionism. With a simple alteration of terms, his argument would read thus:—"If Trades' Union labour is cheaper than free labour, then Trades' Unionists will be employed. If it is dearer, then the London ratepayers ought not to be called upon to pay higher wages." How does Mr. Yates like this adaptation? It is strictly logical and strictly fair, but, unhappily, logic and fairness, as understood by ordinary people, do not enter into the counsels of his clique. Sir Algernon West was the next speaker against the clause, and in his remarks the only point urged was one connected with Imperial policy, and therefore totally inappropriate to a purely municipal discussion. Sir Algernon thought the Bridges Commitee were "playing the game of the Protectionist," against which he strongly protested. That is the worst of politicians in a purely executive body. They quite miss the most important points, and only seek to drag in some pet hobby or antipathy, which is in no way germane to the matter under discussion. Mr. J. A. Baker, who seemed to fancy he was addressing the members of the Highways Committee, said, somewhat irrelevantly, that Belgian tram-rails were better than English, and cost less. Passing over this absurd comparison, it may be remarked that the new Vauxhall Bridge is not going to be built of tram-rails, but of suitable structural sections and plates, which are nowhere found in more perfect forms or of better quality than are evidenced in steel of British manufacture. Mr. Baker merely repeated a popular fallacy in suggesting that foreign steel is cheaper than British steel It sometimes appears to be less costly, but it is certainly dearer when

the tests of strength and endurance are applied.

Some Views favourable to the Clause. We are glad to observe that the views mentioned above were amply refuted by various other members of the Council. For instance, Mr. J. Ratcliffe Cousins said there was really no question of Protection in the matter, and pointed out that in reality a bounty was given to the foreigner by the conditions established by the Council as to wages and hours of labour. Of course these conditions are enforced against the British manufacturer, but they have no effect on the foreigner. Mr. Ratcliffe Cousins further suggested that London ratepayers would cheerfully pay a little more if necessary, when they knew the outlay would have the effect of encouraging home industry, and of keeping men from parading the streets as unemployed. Two other members spoke against the unnecessary importation of Protection into the discussion, and Dr. Napier as a "convinced Free-Trader" supported the recommendation of the Bridges Committee, on the particularly practical and sensible ground that the engineer ought to have the steel manufactured in England, so that proper supervision might be exercised. The remarks of this speaker bring us to the further point that the whole question is one that belongs to the engineer as the responsible professional adviser of the Council, and that it ought to be decided by him alone.

The Incompetency of the Council as Technical Experts. As we have already shown, the majority of the Council consists of men who are troubled with various mental proclivities that totally unfit them for discussing practical—and especially technical—matters in a sensible manner. The question is purely one as to the most suitable type of steel for adoption, and of the most convenient place of manufacture, in order that the new bridge designs may be realised in a manner so as to do credit to the engineer and to render efficient service to the inhabitants of the Metropolis for many years to come. Unlike the elected members of the Council, the engineer has to curry favour with no section of the electors; he has merely to act in accordance with the dictates of his experience and scientific knowledge, and the Council are not justified in interfering with matters they do not in the least understand.

The Commissioners of the 1851 Exhibition and the Proposed Technical College for London.

THE letter from Lord Rosebery to the London County Council, published a few weeks ago in the daily newspapers, has been received with almost unanimous approval by these journals. The proposal to erect a technical college in London, similar to that at Charlottenburg, where students may carry on investigations of a practical character in the technical industries, is certainly one which deserves the fullest and most favourable consideration, even if the details of the scheme should not be approved of by every one. Indeed, the importance of the scheme makes it all the more imperative that the details should be most carefully examined, as everything that is done to carry it out should be done wisely.

At the time of writing, the decision of the County Council upon the proposals submitted to it has just been published, so that the public is now entitled to discuss the whole matter freely, and on a future occasion we may have some remarks to make upon it. But there is one point raised by Lord Rosebery's letter which deserves notice at the earliest possible moment, and which may be discussed freely without touching upon the main questions involved in the scheme, or the part which the County Council is asked to play in it. We refer to the statement by Lord Rosebery that the Commissioners of the 1851 Exhibition are willing to provide a site of some four acres on their lands at South Kensington for the new institution. Here we have notice of the part to be played by a public body, administering a public trust, and it is open to us to consider whether their decision—if it be already a decision—is a wise one, or consistent with their policy in the past.

To understand the present position, it is necessary to know something of the history of this Royal Commission, and this may be briefly sketched. The original function of the Commissioners

was to make arrangements for collecting the necessary funds and for carrying out the scheme for the great Exhibition of 1851. So great was their success in this matter, that when the Exhibition had closed and all expenses had been met, they found themselves in possession of a surplus of (in round figures) £186,000. The duty laid upon the Commissioners, as defined in their charter, was "to increase the means of Industrial Education, and extend the influence of Science and Art upon productive industry," and as they foresaw that it would be necessary, ere long, to build technical colleges and other scientific institutions in the metropolis, and that sites would be required for these buildings and would cost large sums of money, they decided that they could best perform their duty by purchasing an estate, to be kept by them to provide sites for public educational institutions. With the aid of a grant of £177,000 from the Government, which brought into existence the Science and Art Department at the same time, the Commissioners were enabled to buy an area of some eighty acres on the Kensington Gore estate. The first building to be erected on this land was the South Kensington Museum, but other bodies soon applied for sites, and at the present time there stand on that estate the following public buildings

1. South Kensington Museum, The Schools o. Science, and the Department of Science and Art.
2. Natural History Museum.
3. India Museum.
4. Patent Museum.
5. Museum of Scientific Instruments.
6. Royal Albert Hall.
7. Central Tech. Institution (City and Guilds).
8. Royal College of Music.
9. Imperial Institute.
10. Royal School of Art Needlework.
11. The Alexandra Home for Female Students.
12. Museum of Fish Culture.
13. Anthropological Laboratory.
14. School of Art Wood-Carving.
15. Home Arts and Industries Association.

As an instance of the saving of money, both public and private, which has been made possible by devoting the Exhibition surplus to this purpose, it may be mentioned that the City and Guilds Central Technical Institution occupies its valuable site on a lease for 999 years at a rent of 1*s.* per annum.

Now the list given above is a long one, and some fifteen years ago there arose among the public a strong feeling that it was undesirable to crowd all our educational institutions into this area, and that a sufficient number had already been erected there. The public has a short memory, but it is important to remember these facts in view of the present proposals. The Commissioners themselves were forced to consider the position, and having done so, they expressed their decision in their seventh Report, published in 1889, in the following terms:

"The time has arrived when we should no longer consider the grant of sites for public institutions as our principal function, and that, subject to the retention in our hands of sites for Government buildings connected with Science and Art, so long as there exists a reasonable probability of their being employed for that purpose, we should, for the future, endeavour to raise, by disposing of our estate for private building purposes, a considerable income to be applied under our own direction in the promotion of the objects of our charter."

This decision has been carried out, and from 1889 various parts of the estate have been disposed of, the income thus obtained being devoted to the institution of the "1851 Exhibition" Science Research Scholarships, which have played a much more important part in the last ten years in the higher education of this country than is generally recognised.

Now the point of special interest to us at the present time, is the fact that in 1889 the Commissioners formally resolved, after full consideration, to grant no more sites except for *Government* buildings connected with Science and Art. The new college proposed by Lord Rosebery is not to be a Government undertaking, but is to be in the hands of the local authority. Have the Commissioners, then, forgotten their resolution of fourteen years ago, or have they gone back upon it, deciding to make this an exceptional case? It may, perhaps, be urged that the case deserves exceptional treatment on account of its importance, but there are reasons, which to us appear strong, why no departure should be made from the original resolution.

In the first place, the space now available for sites is very limited, and if four acres be given to the London County

Council, there will be four acres less for any Government educational buildings which may be needed in the future, or for extensions of buildings already there. And in the second place, if four acres be all that can be given, it seems quite inadequate for the purpose. Mr. Chamberlain emphasised this point when speaking at Birmingham University a short time ago, and it ought not to be overlooked. If London is to have a "Charlottenburg" college within her gates, let it be worthy of the metropolis and on a handsome scale, with full provision for all eventualities. The question might also be raised whether such an institution can properly be built in such a locality. It is to be of a different character from that of the technical colleges already erected there, and will involve the installation of furnaces and much heavy machinery. The Commissioners have profited by disposing of their land for building purposes, and they must not do anything to depreciate that land or the dwelling houses upon it, by placing in close proximity a building where various manufacturing processes are to be carried on, and which may of necessity have furnaces and chimney-stacks.

But apart from the question of the suitability of this site, there is the other question to be considered—the advisability of cramming all the principal educational institutions of London into this small area. In 1889 it was felt that a sufficient number had been erected: is that no longer true in 1903? One is reluctant to criticise any single feature of this great scheme which has been placed before the country by Lord Rosebery, lest one should seem to oppose it; but the point we have raised ought not to be considered in that light, but rather as a discussion of the best means of carrying out the scheme. The Commissioners of the 1851 Exhibition are naturally anxious to help, but they do not appear to us to have chosen the best way. If the remaining land in their possession is not to be kept for Government buildings, we believe the Commissioners could give more valuable assistance by selling it and devoting the proceeds to the foundation of good scholarships to be held by picked men at the new college, wherever and whenever it may be erected. Such scholarships would enable many men of talent, who are without private means, to spend two or three years in investigations of a practical character, when without such aid they would be forced to curtail their studies, and to go out into the world to earn their living.

For these reasons we hope that the Commissioners have not yet finally decided on this question of providing a site. They have done noble service in this respect in the earlier years of their existence, but to our mind the work they have done since they resolved that the grant of sites for public buildings was no longer their principal function, is as noble, and has been of the greatest value to the whole Empire (for their research scholarships are granted in the Colonies as well as in the Mother Country). This later policy might with advantage be extended, if the new scheme is successfully carried into execution. But if the final decision has already been made, and the Commissioners' part is to be the grant of a site, is it not worth while to consider whether the scheme could not be more effectively and more economically carried out in connection with an institution already existing on that estate—the Royal College of Science? The strongest argument that can be urged in favour of the Commissioners granting a site in spite of their old resolution, is that, although the new college under the present scheme is not to be a Government building, it ought to be, as it is intended to supply the needs, not of London merely, but of the whole country. As one speaker at the meeting of the County Council said, the scheme is "trying to do a national thing in a local way." The multiplication of institutions is not desirable, and we believe the same good purpose would be served by extending the field covered by an existing institution, and that the Royal College of Science—as a Government undertaking—is the proper one for this purpose.

It is to be hoped that when the scheme comes up for full public discussion, this view may be properly considered.

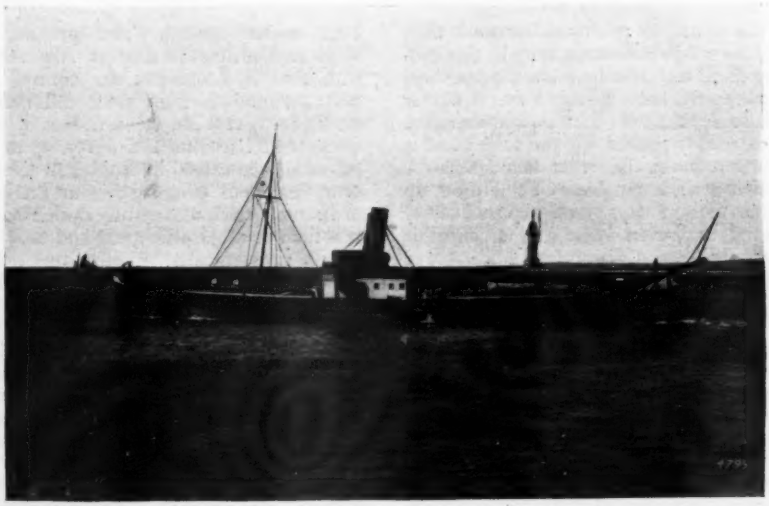
ENGINEERING PROGRESS.

A New Suction Dredger.

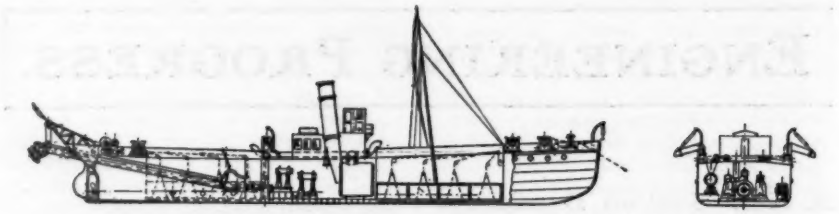
UNTIL about thirty years ago dredging operations were performed almost invariably by dredging machines of the well-known bucket system, in which a series of buckets with sharp edges are kept constantly at work scooping up the bottom and discharging the spoil brought up into barges lying alongside. A process known as the "grab bucket" system was introduced shortly after this, in which a kind of bucket, constructed so that it can be mechanically closed or opened, suspended by chains from upright cranes, is dropped to the bottom with its jaws open, and its weight forcing it into the mud, is closed and lifted, and the contents emptied into the hold of the dredger.

Laborious and expensive to work, these two systems have, nevertheless, had of necessity and from lack of better appliances, to be adhered to, and as a consequence the fight to keep the channels open to those vessels desirous of calling at them has, in several notable instances, not proved altogether successful.

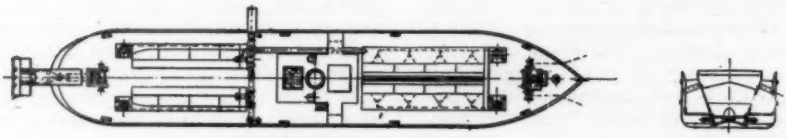
At the time of the construction of the Suez Canal, M. Bazine, an engineer, invented and brought out the system known as the Suction system. This process, briefly described, is the action of a centrifugal fan pump revolving at one end of a tube whose other end is suspended over the bottom it is required to dredge. The revolution of the fan causes a strong attraction up the tube, and it is this updraught or suction process which draws after it up the tube the light silt or sand bottom over which it is placed.



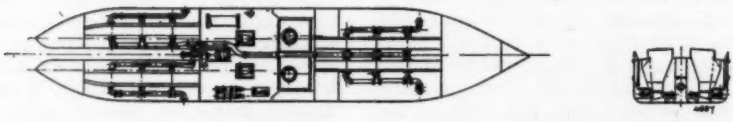
THE NEW STEAM DREDGER "NIKOLAUS."



LONGITUDINAL SECTION. SECTION THROUGH MACHINE ROOM



PLAN OF DECK. SECTION THROUGH FORE PART



HORIZONTAL SECTION. SECTION AFT.

DETAILS OF DREDGER "NIKOLAUS."

Now it will be readily understood that, with the solid matter caught up by this process, there will also be a large percentage of water, the latter being of much lighter consistency than the bottom, and therefore more readily sucked up the tube; and it is precisely this fact that has made the suction process capable of being used, up to the present day, practically exclusively in sand, and, even when dealing with this material, it has only been found possible to so far improve the process as to enable it, under the most favourable condition, to bring up 45 per cent. of solid matter to 55 per cent. of water. The enormous waste of power is made apparent at a glance by this statement.

Though sand is a very important factor to be dealt with in the up-keep and clearing of channels and river mouths, yet, on account of its light character, it is cheaper to work than any other bottom, and can be consequently more or less certainly kept under control. The problem of ways and means of dealing successfully with, that is, keeping under control, the vast accumulations of mud and muddy sand or clay that are met with in our great docks and harbours has never, up to the present, been solved in England. Nearly every engineer connected with dredging or harbour work of any description has at one time or other attempted and failed to hit on some means by which this source of trouble could be eliminated. The advent of the suction system and its wonderful success when dealing with the sandy bottoms met with at Suez and in the canal works generally, caused great hopes to be raised, but on the attempt being made to work the process in mud, the tube and the fan fitted on the experimental craft became clogged with the mud almost immediately, and the experiment was abandoned. The old systems were continued with, and improved in

minor details from time to time, but the great problem was unsolved, and the difficulties to be contended with increased year by year.

This has been changed. The luck fell to the German Government to have in their employ an engineer, by name Herr Otto Fruhling, who, realising the vast importance of combating the drawbacks arising from the enormous accumulations of mud and clay refuse in the harbours, canals, and river mouths of his own country, set to work to solve the problem. He recognised that it was impossible to attempt to devise any improvement in any existing system but that of dredging by suction, the grab and bucket processes having been brought to the highest pitch of excellence they could ever attain. The chief difficulty he had to overcome was the fact that, with the open-mouth tube, it was inevitable that by far the greater portion of power exerted should be wasted in bringing up practically pure water when dealing with heavy soils. In 1898 he had succeeded in devising a method by which many obstacles were swept aside, and he was able to offer his Government in particular, and the world in general, his machine.

The vessel in which the apparatus is to be fitted has her stern half divided in the centre, thus leaving a lengthy narrow gap. In this gap is fitted a large and very powerfully constructed girder, projecting over the vessel's stern, and working on trunnions fixed amidships. The suction pipe or tube is run along the entire length of the girder (a flexible steel tube connecting it with the centrifugal pump in the engine room), its open end being enclosed in a large oblong box (called a dredger-head) fixed on the end of the girder and at right angles to same. A powerful crane is erected above the end of the girder projecting over the stern, and with this crane the girder is lowered to the bottom or raised, as required. It is in this dredger-head, fitted on the end of the girder, that the secret of the invention lies. Along the edge of the box are fitted long prongs or spikes, the girder is lowered till the dredger-head rests on the bottom to be dredged, the spikes dig into and break up the ground, the centrifugal pump is set working, and the vessel steams ahead. As she proceeds the dredger-head is dragged along, and becomes filled with mud or clay, or whatever the bottom encountered consists of. As the mud, etc., enters the dredger-head jets of water at very high pressure are projected on to it from a number of openings arranged along the edge of the dredger-head just above each of the spikes. These jets play on the mud brought into the dredger-head, and atomise it; but the supply of water can be regulated, so that only just sufficient is admitted to reduce the mud to a consistency which can be taken up the pipe, and through the fan, into the holds of the vessel, without clogging them.

Moreover, no water is admitted into the dredger-head, except such water as has been admitted through the high-pressure nozzles, the reason of this being that the whole of the opening of the dredger-head is buried in the bottom while the vessel is dredging, and therefore only solid mud matter can gain admittance into the dredger-head. The regulation of the water supply is, therefore, the easiest of matters, the spoil as it comes up being delivered into the holds of the dredger or into barges alongside through delivery pipes. Men experienced in the subject standing by them can tell at a glance whether too much or too little water is being admitted. The spoil dredged into the holds of the dredger or the barges consists, so far as is practically possible, entirely of solid matter, and therefore the least possible amount of power is wasted in dredging: all is good work.

The chief advantages of this invention may be given as follows:—

In the first place, the cost of working this system is claimed to be much less than that entailed by the use of any other.

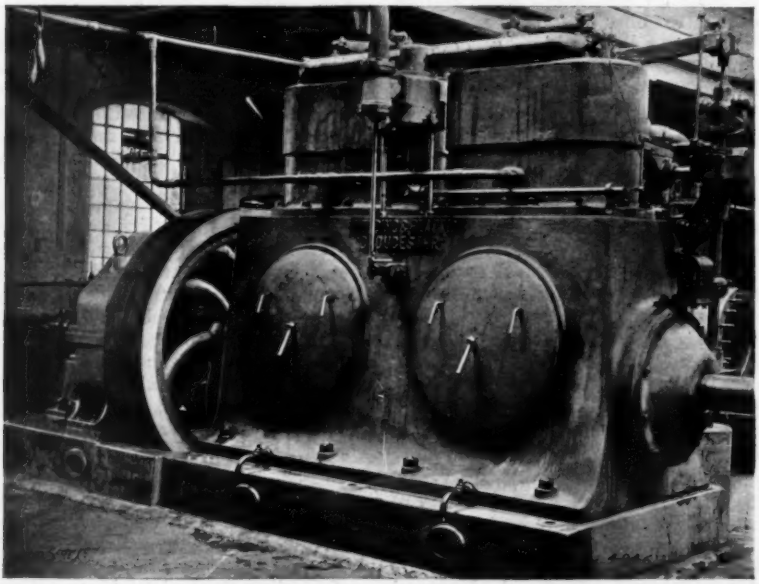
Secondly, the speed with which the vessel does its work is superior to that of the grab or bucket systems.

To begin with, the grab or bucket types of dredger are only able to work by means of hauling themselves in the direction desired slowly, by their winch power

working on great ropes and hawsers affixed to buoys, banks, or dock walls, etc., resulting in hindrance to navigation being frequently caused, when work is being carried on in narrow rivers or docks. These chains and hawsers have to be affixed and hauled in when the vessel starts and finishes operations causing additional waste of time. Grab dredgers, moreover, are unable to work with barges owing to their cranes and grab buckets constantly swinging overside, and, consequently have no sooner filled their own holds than they must proceed to the dumping ground, shoot their cargo out, and return before being able to recommence operations. The difference in speed while actually dredging between grab or bucket dredger and those of Herr Fruhling's type, may be gauged from the following figures taken from a report dealing with the actual performances of the best vessels of each system.

A dredger working with the Fruhling apparatus for the German Government in the Kiel Canal, raises an average of 600 tons of stiff mud in 12 min., the percentage being about 85 per cent. mud and 15 per cent. water. The best existing dredger of the grab-bucket type working in England, raises 1,400 tons of spoil in 1 hour and 45 min., the percentage being about 30 to 35 per cent. at most of solids to 70 to 65 per cent. of water. And one of the most modern of bucket dredgers, working at another large English port, raises 700 tons of spoil in about 1 hour and a-half. The percentage of solid and water in this case being about equal to that in the case of the grab dredger.

A point of further interest attaching to the fact that owing to the deep draught of the new German liners, which churn up a large quantity of mud in the Jade Estuary, Wilhelmshaven, and seeing that the system of dredging hitherto in use in Prussia is not adequate to cope with this, the Marine Treasury have under construction a giant dredger, built on the Fruhling system, by means of which, in future, the



NEW TYPE OF FOUR-CYLINDER GAS ENGINE.

navigable water of the Jade Estuary will be maintained at a proper level. This large dredger is of 4,500 tons displacement, and of 2,000 odd h.p.; and, working at a depth of 14 m., can remove 3,600 cub. m. per hour (which is equivalent to about 6,000 tons).

Almost as important as the questions of cost and speed is the fact that the Fruhling dredger is the only type of machine existing that will dredge the bottom level. That this is a fact will be at once admitted, when it is considered that the Fruhling type drags along the bottom a large box of at least 13 ft. in width, while it is equally obvious that a succession of buckets digging into the bottom will dredge a hole, or succession of holes, as will also the dropping of large grab buckets to the bottom, and the action of an open-mouthed suction pipe working close to the bottom. The making of these holes is of very serious importance, as, if it occurs near to dock walls or other harbour constructions, it is extremely liable to undermine them and cause them to subside.

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A Four-Cylinder Gas Engine.

THE accompanying illustration is that of a gas engine of the vertical enclosed type, attaching to which are several points of interest. It is the outcome of the demand which exists, particularly in connection with the generation of electric current for lighting purposes, for an engine able to meet sudden demands of power without suffering any appreciable drop in speed, and possesses an adaptability for work requiring a maximum steadiness for cyclical variation or variation caused by a sudden increase or decrease of loads.

The makers, Messrs. Fielding & Platt, of Gloucester, claim that these points have been met by the employment of four cylinders, whereby two impulses are obtained at each revolution, and by the introduction of a system of balanced cranks, which displaces the older and more cumbrous method of balance weights. Further, a graduated system of governing contributes to the steadiness of revolution, the governor, which is of the ball type, never cutting out.

The even turning effort obtained by this system of governing, and the use of four cylinders, necessitates the employment of a flywheel of only moderate weight.

Ignition is effected by means of an improved electro-magnetic apparatus (worked from the front cam shaft), thus avoiding the use of batteries and induction coils.

The main working parts and a greater portion of the valve gear are enclosed within the main body, so that lubrication is thoroughly effected by the splash system.

Notwithstanding that the connecting-rods and cranks are enclosed, the casing is specially designed with large access doors, two of which are of dished form, made of thin steel plate, secured by central bolt so that either of these doors could be removed by one man in less than a minute.

When all doors are removed the engine is practically an open one, so that the objectionable feature in some enclosed engines of difficulty of access to parts inside the casing is overcome in a very satisfactory manner.

The engine is started by means of compressed air, which is stored in reservoirs, at a pressure of about 100 lbs. per square inch, the pressure being maintained by a small compressor. The opening of the air-admission valve suffices to start the engine, this valve closing when the other cylinders fire the first charge.

Vibration has been reduced to a minimum, so much so that the engine has been run satisfactorily without even being bolted down.

All parts likely to be affected by heat, including the exhaust valve, are water cooled, so that the likelihood of premature ignition taking place is very improbable.

The cylinder dimensions are: diameter 13½ ins., stroke 15 ins., and the engine, at a normal speed of 250 revolutions per minute, is capable of developing 180 b.h.p. when using producer gas.

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SELF-PROPELLED OIL ENGINE.

New Machinery at the Royal Show.

Self-Propelled Oil Engine or Tractor.

THIS machine, exhibited by Messrs. J. B. Petter & Sons, of Yeovil, has been constructed to meet the requirements of the Light Locomotives Act, and is provided with a motor of about 12 b.h.p., using common paraffin lamp oil, at a working cost of about 6*d*. per hour. Provision has been made for cooling the circulating water required for the cylinder by air, so that it will work without needing additional water.

Two ordinary speeds, both controlled by one friction clutch, are provided, viz. 2 and 4½ miles per hour respectively, but these can be altered to suit requirements; there is also a reversing gear. The gear wheels are secured to a sleeve carried on the crank-shaft. These mesh with corresponding gear wheels, which slide on three feathers on a countershaft, from which the power is transmitted by a Renolds chain to a wheel surrounding the differential gear on the live back axle. The engine is fitted with an automatic tube ignition, in which no lamp or electric arrangement is required for igniting the explosive mixture after it has been started. It is mounted on springs, and by means of the differential gear axle both rear wheels are used for propelling purposes.

This tractor is intended to be used for drawing ploughs, cultivators, mowers, reapers, etc. It will also drive a thrashing machine and a full-size plant of barn machinery. It is provided with an easily removable platform which can be loaded with goods to the extent of about two tons, and, in addition, an ordinary farm wagon can be drawn behind.

It therefore has a very wide field of service on farms and estates, since, in addition to driving the machinery for cultivating the land and preparing food, it becomes the farmer's own light railway for conveyance of goods and produce to and from his nearest station.

The great simplicity of the motor, and the convenient arrangement of the working parts, which are all easily accessible, make it possible for the machine to be entrusted to the care of an intelligent farm servant.

Oil Engines.

THE largest oil engine on the ground was that exhibited by Messrs. R. Hornsby & Sons, Grantham.

It was shown driving by a belt connection, a Brush dynamo, the current from which was utilised for lighting the stand.

The cylinder is 25½ ins. in diameter, and 125 b.h.p. was developed when using Texas oil at 2½*d.* per gallon.

An engine shown by Messrs. Blackstone & Co., of Stamford, calls for mention, in that it was fitted with a new system of vapourising and igniting. The charge is ignited by asbestos or other refractory material contained in a chamber, to which the charge is admitted by a timing valve. This igniter is surrounded by an annular chamber in which the oil, mixed with a due proportion of air, is vapourised, its heat being maintained by the explosions in the igniter. Encasing the vapourising chamber is an annular space sufficiently hot to heat the air which is drawn through it on its way to the vapouriser.

Another interesting point on the engine is the new form of governor, which is extremely neat and effective. It is an ingenious combination of the centrifugal and hit-and-miss types, but is superior to either, inasmuch as it never slips catch having once started to do its work.

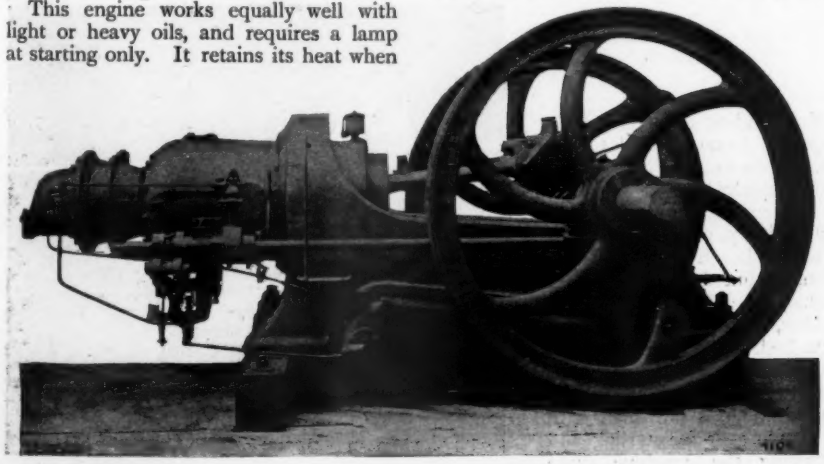
Yet another feature brought out by this firm is the self-starter, which can be, when desired, fitted to the engine without outside or separate containers or pipes, and, we believe, they have the first portable oil engine fitted with a whistle.

This engine works equally well with light or heavy oils, and requires a lamp at starting only. It retains its heat when running light, is very economical, and will pull its full load continuously.

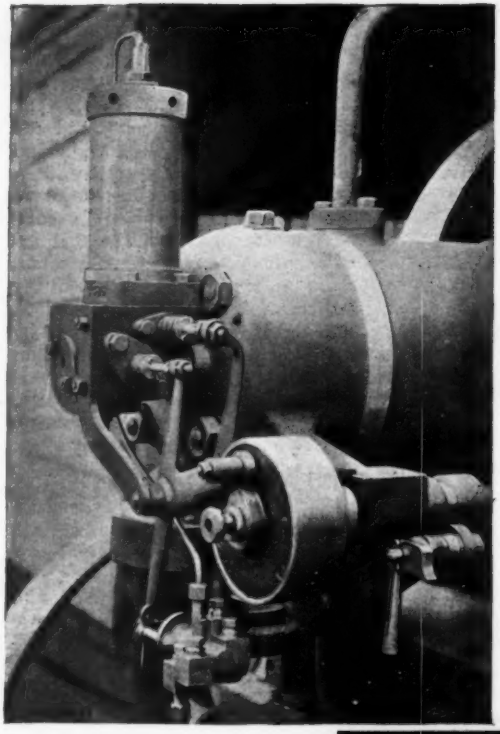
Another oil engine of new design was exhibited by the Forward Engineering Co., Ltd., of Birmingham. In this the timing valve is dispensed with, and the vapouriser is placed some distance behind the cylinder with the air-inlet valve interposed between the two. The portion of the charge in which ignition is commenced is artificially cooled so that explosion will only take place when it comes in contact, under heavy pressure, with the hot vapouriser. A light is required at starting only, the charge being fired by the heat of the vapouriser. This engine is reported to have given remarkably good results on trial, some details of which, together with full drawings, we hope to place before our readers in an early issue.

A Petrol Motor Mower.

Messrs. Ransomes, Sims & Jefferies, Ipswich, have for some time past been engaged in experimenting with and perfecting a motor-driven lawn mower, as a result of which they have been enabled to put on the market machines which are both simple and compact in design. The machines are made in three sizes—42-in., 30-in., and 24-in. cutting width. In the 42-in. the cutting-barrel, bottom blade, front



125-B.H.P. HORNSBY-AKROYD OIL ENGINE.



END VIEW OF MESSRS. BLACKSTONE'S OIL ENGINE.

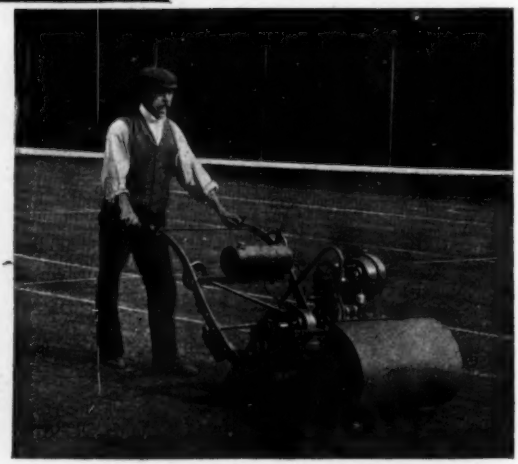
roller and box are carried on a separate frame, hinged to the main axle to allow it to follow the inequalities of the ground.

The cutting cylinder is driven by a 6-b.h p. petrol motor with "Simms-Bosch" magneto-ignition, mounted on the main frame, to which the driving rollers, seat, etc., are also attached. The power is conveyed to the cylinder by chain gear through a reducing arrangement which is furnished with a simple gear for starting and stopping the machine quite independently of the motor. There is also a separate clutch for putting the cutting cylinder out of gear when it is required to roll the grass only.

All the handles and levers for starting, stopping, and emptying the grass-box are arranged so as to be easily within reach of the attendant sitting on the machine.

When not required as a grass-cutter the machine can be used as a roller; and when required for heavy rolling, the cutting cylinder can be removed and extra weight easily added by separate weights; 7 cwts. or less can be added in this way. A pulley can be attached for using the motor for other purposes, such as driving a chaff-cutter, oat-bruiser, pump, etc.

The 30-in. machine is of lighter construction for use on smaller lawns and for hilly work, such as golf links. In this machine the attendant walks behind. A $3\frac{1}{2}$-b.h.p. motor is used, and this machine, like the 42-in., is fitted with the patent arrangement for emptying grass-box.



MOTOR-DRIVEN LAWN MOWER.

ENGINEERING ABSTRACTS.

MATERIALS AND MEASUREMENTS.

Tests Applied to Paints used for the Protection of Iron.

THE necessary qualifications of a paint to prevent rust are: (1) That it shall be impervious to and unaffected by moisture or atmospheric influences; (2) That it shall form a surface sufficiently hard to be durable and yet sufficiently elastic to conform to the expansion and contraction of the metal; (3) That it shall adhere firmly to the surface; (4) That it shall not corrode the metal. Among the various tests for ascertaining the value of paints as a protection against rust are the following: (1) Loesner's steam test; (2) "The water and moisture test"; (3) Immersion in water; (4) Test of the electrical insulation; (5) Heat test. The object of this investigation was to make a comparison of these methods and to decide whether the value of a paint in actual use can be ascertained by laboratory experiments. This permitted, at the same time, a comparison of the various paints themselves. The general results are summarised in the table below. From this it appears that the paints which best withstand the action of water or atmospheric agencies are those which are most attacked by heat, and *vice versâ*. For the most complete protection of iron it would seem to be essential to use a paint in which the pigment combines with the oil, as with the lead paints, or a varnish carrying pigment. These tests well show how inefficient a protection is linseed oil without a pigment.—**A. H. Gill** and **C. C. Johnson**, *Tech. Qtrly.*, *Vol. XVI.*, *No. 1*, pp. 32–40.

SUMMARY OF TESTS.

Paint.	Loesner.	Water and Moisture.	Immersion.	Electricity.	Heat.
Dixon	A.	A.	Sl. A.	<300	Not attacked.
Durable metal ...	Sl. A.	N. A.	Sl. A.	547	Cracked.
Mineral brown ...	A.	Sl. A.	Sl. A.	633 / 743	Not attacked.
Bessemer	A.	V. M. A.	A.	<300	Not attacked.
Raw oil	V. M. A.	V. M. A.	V. M. A.	——	——
Boiled oil	V. M. A.	V. M. A.	V. M. A.	<300	——
Black enamel ...	V. M. A.	——	——	<300	Brittle; peeled off.
Red lead	N. A.	N. A.	N. A.	1707 / 647	Brittle; peeled off.
Red lead and lucol...	A.	N. A.	N. A.*	438	Brittle; peeled off.
Red lead 30% / White lead 60% ..	Sl. A.	N. A.	N. A.	660	Brittle; peeled off.
First coat red lead / Second coat white lead	Sl. A.	N. A.	N. A.*	850	Brittle; peeled off.
Barytes and boiled oil	A.	A.	Sl. A.	560	Peeled off.
Oxide iron	A.*	Sl. A.	Sl. A.	<300	Not attacked.
Zinc white	S. A.	A.	A.*	630	Peeled off.
Zinc and barytes ...	A.	——	——	697	Not attacked.
White lead and zinc	N. A.	A.	A.*	——	Brittle.
White lead	Sl. A.	Sl. A.	Sl. A.*	510	Peeled off.
White lead and lucol	Sl. A.	Sl. A.	Sl. A.	827	Peeled off.
Lead and barytes ...	A.	——	A.*	750	Peeled off.
Red ld. and graphite	Sl. A.	——	——	573	Peeled off.
Red ld. and red ox.	Sl. A.	——	——	917	Peeled off.
Red ld., red ox. and lucol	Sl. A.	——	——	——	——
Rosin varnish ...	V. M. A.	A.	V. M. A.	540	Peeled off.
Half rosin varnish ...	A.	Sl. A.	V. M. A.	395	Not attacked.
Kauri varnish ...	Sl. A.	Sl. A.	Sl. A.	395	Not attacked.

A. = Attacked. S. A. = Somewhat attacked. Sl. A. = Slightly attacked. V. M. A. = Very much attacked. N. A. = Not attacked.

* Coating tender.

Protection and Preservation of Wood.

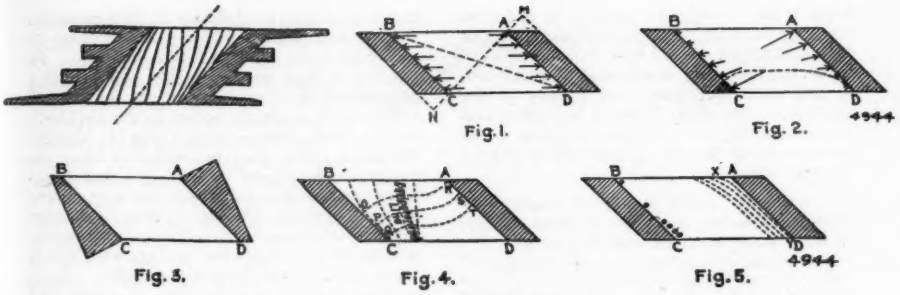
It is not claimed that wood cannot ultimately be disintegrated and destroyed by attacking flame, but it is claimed that wood may be so treated that it will not of itself hold flame, except perhaps momentarily. Certain chemical solutions, when injected into the cellular structure of wood and afterwards dried, leave a residual deposit which has in in one case a preservative and in another a fire-resistant effect. The mechanical saturation of wood is really a new art. It found its first development in apparatus designed to saturate timbers with preservative solution. Wood treated to make it fire-resistant is subjected to many stringent requirements not essential for preservative treatment. For instance, the saturation must be complete to the heart, the colour must not be impaired, the strength of fibre must be preserved, and there must be no linger of flame on withdrawal of attacking flame. To comply with these requirements the strength of solution must be as high as possible. "Gaseous emission" chemicals were the only materials used, up to five years ago, in any commercial fire-proofing plant. It became necessary to seek for materials, acting on a reverse principle from that of the gaseous emission, and after years of effort sulphate of aluminium was found to be the substance endowed with the property of fire-resistance beyond any previous conception. This satisfactory result comes from the fact that sulphate of aluminium under flame is reduced to pure alumina, which has the property of expansion in the cells of wood to two, two and a-half or three times the original volume of dry sulphate, and in doing so it interposes a compact mass between flame and wood fibre; therefore the fire resistance achieved in saturated wood proceeds from the massing within it of an inert and infusible substance which, from its non-conducting character, bars destructive heat, giving absolute negation to flame for a prolonged period of time. This seems to show that the "massing" principle is correct, and the principle is further illustrated and confirmed by its extension to the preservation of existent structures from attack by fire. A chemical substance was discovered possessed of extraordinary penetrative power, a simple application entering ¼ in. below the surface of oak. By subsequent coatings other chemicals, making chemical union with the first, insured adhesion and condensation; and an enamel grew upon the wood surface possessing a fire-resistance over six times that of wood treated by sulphate of ammonia solution.—**Joseph L. Ferrell,** *Proc. Eng. Club, Philad., Vol. XX., No. 2,* pp. 209–230.

CONSTRUCTIONAL.

The Stresses on Skew Arches.

On the 14th May last, a Monier arch of considerable size, and built at an extreme skew, collapsed at Bendigo. The failure was sudden and unexpected, unlike the recorded mode of failure of Monier arches that have been tested to destruction in Europe and elsewhere, in which cases numerous and conspicuous signs of distress were visible long before the final collapse. The contractor at once retained the services of the writer of this paper, and, in describing the disaster, expressed doubt as to the correctness of the received theory of skew arches. These doubts appeared reasonable, and led the writer to examine the matter closely. Assuming the abutments to be immovable, which must be very nearly correct, as they are small in height, massive in section, and founded on solid rock, and that the arch was perfectly and uniformly elastic, so that the stress in any given direction would be proportional to the change of dimensions, the following calculation was made. The arch was supposed to have been pressed down to a given small extent by its own weight, and the superincumbent load, and the consequent reduction in length of lines traced on its extrados in the positions AB and AC were computed (Fig. 1), the result being that the percentage of shortening in the direction AC was found to be almost exactly double that in the direction AB, or in any line parallel to AB. Consequently it followed that the heaviest stress in the arch was diagonally across from A to C, that the stress in the direction AB was only half as great, while that in the direction BD was found, by an extension of the same calculation, to be excessively small. In fact, the distribution of thrust along the faces of the abutments, instead of being as in Fig. 1, which illustrates Rankine's theory, must be something like Fig. 2, the magnitude of the thrust at or near the acute angle of each abutment being greatly increased, and its direction altered in an unfavourable manner, while at the obtuse angles the thrust would be very small indeed. Hence the abutments should have had the form shown in Fig. 3, being strengthened when the heavy thrust occurred, and for economy reduced at the other end.* After removal of the debris it was found that the acute angle C had been absolutely pulverised, though of good, strong concrete, thus bearing witness to the great local intensification of stress. The heavily-shaded area in Fig. 2 shows the extent of

* Fig. 3* is the plan of a skew arch reproduced from Rankine's "Civil Engineering," p. 429.—Ed. F.M.



STRESSES ON SKEW ARCHES.

destruction of the abutment, and the dotted line extended from it is the boundary dividing the portion of the arch which fell from that which remained standing. In view of the preceding, there seems to be no reasonable doubt but that the accepted method of designing the abutments of skew arches was most seriously in error. It appeared that a conclusion, so important and far-reaching as the above, should be checked and verified in every possible way, and further, that definite rules or formulæ giving the magnitude and direction of the thrust at various points along the abutments, were very desirable as a guide to designers. The writer therefore placed himself in communication with the leading experts in elasticity known to him, and found them unable to supply the requisite formulæ. The mathematical theory of elasticity, though long a subject of study, and possessing a considerable literature, appears not yet to be sufficiently developed for the purpose. Mr. Love, the demonstrator of physics at the University, after failing to indicate any direct mathematical solution, made the ingenious suggestion that, as there is a very striking analogy between the laws regulating the distribution of stress in an elastic solid, and those regulating the flow of electricity in a conductor, a metallic model of the bridge should be made, and a current of electricity being passed through it, its equipotential lines should be determined, and that a series of lines drawn at right angles to these would give the direction of the stress, and by their convergence or divergence would indicate where the stress became intense or the reverse. The experiment was actually carried out, and the result is shown in Fig. 4, where it will be noted how greatly the current density and, by analogy, stress is intensified in the vicinity of the acute angles, *A* and *C*. The actual numerical result was that in a bridge of the proportions of that at Bendigo, three-fourths of the whole thrust was resisted by less than one-half of the length of the abutment, one-half of the total thrust by one-fifth of that length, and one-fourth of the total thrust by less than one-thirtieth of that length, at the weakest and least effectively backed up portion of the abutment. These results are indicated by the position of the points *O*, *P*, *Q*, *R*, *S*, *T*. One-fourth of the electric current passed between *A* and *R*, or *Q* and *C*, one-half between *A* and *S*, or *P* and *C*, and three-fourths between *A* and *T*, or *O* and *C*. The model experimented upon consisted of two massive copper abutments, connected by a thin German silver band to represent the arch. The writer's own experimenting was of a different sort. He constructed and tested an indiarubber model having drawn upon it parallel lines or circles of known diameter, the deformation of which would indicate the direction and magnitude of the stress. This model gave unmistakable indications of great intensification of stress in the vicinity of the points *A* and *C*, but was troublesome to manage. An inverted model was therefore made of thin sheet indiarubber, which gave very definite and consistent results. These are shown in Fig. 5. The lines *AD* and *XY* were originally parallel, but when the arch was loaded *AX* increased enormously, showing great intensification of stress, while *YD* remained nearly unaltered. The same peculiarity is shown by the small circles drawn near the line *BC*. Most of these remained almost unchanged, but those near the point *C* were greatly distorted, showing a very heavy stress approximately in the direction *AC*, which is quite contrary to the received theory. The conclusion, then, is that the views hitherto held as to the distribution of stress in skew arches are most seriously and dangerously in error, and that an elaborate and costly series of experiments on a fairly

large scale is urgently needed in order to establish reliable rules for the designing of such structures. Until such experiments are made, the following provisional rules are submitted, as representing the results of the small experiments at present available, and as constituting at any rate a distinct improvement on the old unscientific system of the text books.

Provisional rules for proportioning the arches, abutments, and piers of skew bridges in brick, stone, concrete, and Monier :—

Angle of skew.—90 degs. signifying a square bridge.

Above 80 degs.—Design as at present.

80 degs. to 70 degs.—The acute angle of each abutment and pier to be replaced by a right angle. See lines *AM*, *CN* in Fig. 1.

70 degs. to 60 degs.—Increase the thickness of the arch by one-fourth at the points *A* and *C*. Such increased thickness to diminish in all directions until it vanishes at a distance equal to one-fourth of the skew span. Acute angles of piers and abutments to be replaced by right angles, and the thickness increased one-fourth at *A* and *C*, such increased thickness to diminish in the same way as that of the arch.

60 degs. to 50 degs.—Same treatment as the last, except that the increased thickness of arches, piers, and abutments be one-third.

50 degs. to 40 degs.—Same treatment as the last, except that the increased thickness in each case be one-half.

—**Prof. W. C. Kernot,** *Proc. Vic. Inst. Eng. (Australia), 1903.*

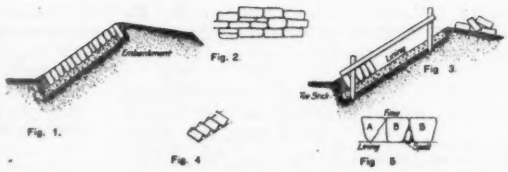
The Assimilation of Railway Practice in respect of Loads on Bridges up to 200 ft. Span.

AFTER remarking that it is undesirable to carry standardisation to such an extent as might tend to arrest advancement in type or design, the author points out that it is of the utmost importance that uniformity should be arrived at with regard to the loads to which structures may be subjected. Bridges for railways may be divided into two classes—(1) those carrying railways over highways, waterways, rivers, etc., the loads being guided in their course by a track fixed in position; (2) those carrying highways, etc., over railways, with or without a fixed track to guide the loads. With the first-named class the general practice has been for the engineer to select the heaviest type of engine in use on the line as a basis for the maximum load for small spans, and to assume a combination of the engines giving the greatest stress for larger spans. Each of the large railway companies has distinctive types of locomotives, and, as there is an extensive interchange of traffic between the companies, it appears desirable that all railway bridges in this country should be strong enough to take the heaviest engines or combination of engines in use on any railway. Tables accompanying the paper contain data showing the equivalent uniformly distributed live loads derived from the maximum bending-moment caused by engines running on different British railways. The figures shown include an addition of 2½ per cent. for possible future increase. In passing it may be noted that the growing practice of building locomotives with small wheels close together, points to the necessity of the cross-girders being kept at shorter distances apart than has hitherto been the practice. A second table shows that highway bridges are subjected to very heavy weights, and not infrequently heavier weights than those shown on the table pass along the streets of towns drawn by two, and sometimes even three, traction engines. It is evident that the introduction of steam, and more recently of electric tramways with heavy cars, and the general increase of loads passing along streets and highways, have raised the standard of weight, and it is a question for consideration what, from such a great variety of loads, is a reasonable average weight per square foot to accept as a standard. The standard loads which are reasonable to adopt as a basis for calculating the strength of railway bridges for spans up to 200 ft. may also be deduced from the data furnished by the tables.—**A. Ross,** *M. Inst. C.E., Engineering Conference (Railways Section), (Vol. CLIV., Proc. Inst. C.E.).—C.S.I.*

The Design of Slope-Walls.

SLOPE-WALLS for the protection of river, canal, and reservoir banks are built as shown in Figs. 1 and 2. The longest dimension of the stone is laid parallel with the axis of the canal or river. Experience has shown the necessity of splitting up slabs into blocks readily laid and bedded by hand. It is our opinion that gravel lining, as shown, is one of the most important and necessary features of a well-made slope-wall. It serves a twofold purpose, making it easy for the workmen to properly bed the stone, and adding to the protection of the sub-soil from wash. On rivers or reservoirs subject to wide fluctuations in level, the lining is even more necessary than on canals; for the surface water, flowing down the face of the slope-wall, will cut rivulets beneath it, unless proper lining is provided. A thickness of gravel lining of from 4 to 8 ins. will suffice. The thickness of the stone for the slope-wall itself, ranges from 6 ins. to 24 ins. In slope-wall masonry, on river embankments subject to blows, a thickness of 8 to 10 ins. is an advisable minimum. On reservoirs or canals, where blows from boats are not frequent, a less thickness may be used. A minimum length of 12 ins. is often specified for the stones, and is not unreasonable. Slope-wall paving is laid to break joint, as

shown in Fig. 2; because if the toe is washed out, the stones span the space, and prevent crumbling away of the wall. A wall with 1½-in. maximum joints serves the purpose of protection from erosion, and any expense incurred in better dressing is merely "for looks." In laying a slope-wall, "frames" or "profiles" should be set about 20 ft. or 25 ft. apart, as shown in Fig. 3. Stakes are driven as shown, and a 1 by 4-in. profile-stick is nailed to the stake at the proper grade, as determined by the Y-level. The workmen then stretch a string from the bottom of one frame to the bottom of the next one, and thus have a line to which they can accurately lay the face of the wall. Sharp-pointed stones like *A* (Fig. 5), should not be allowed; but stones like *B* are not objectionable, provided the joints are properly filled. In canal work, it is customary to lay a 12 by 12-in. toe-timber or stick, as shown in Fig. 3, but we question the necessity for a toe-stick, under ordinary conditions. In river-work, a toe-stick, resting against piles, is often used, and in some cases a line of piles is substituted, which is an expensive and not altogether satisfactory solution of the problem.—*Eng. News, Vol. XLIX., No. 24*, pp. 524–526.



DESIGN OF SLOPE-WALLS.

Dredging with Rotary Cutters.

HYDRAULIC dredgers have hitherto been employed on sand or light silt, which yields to the current drawn into the nozzle by the action of the pumps. For dredging clay rotary cutters fitted to the nozzle of the suction pipes have been used. The author's experience of rotary cutters has been with a dredger designed for the purpose of excavating clay for dock extension. The clay being silty, it was thought that it would be easily broken up by the cutter, but this was not the case. The dredger was first operated at a small depth where the soil was loamy, and the cutter proved efficient; but when the clay was reached at a greater depth the openings between the blades of the cutter became clogged, and the proportion of clay in the water discharged was extremely small. A width of some inches was then cut off each blade. When again tried there was but little clogging, but the blades did not cut the clay very well. A new cutter was then built, with narrow spiral knives, and proved to be more efficient than the first; but even with this cutter the quantity turned out per hour was never more than 60 per cent. of that contracted for. The efficiency of a cutter evidently depends on the form of the blades, the angle at which they are set, whether they are straight or spiral, and on the openings between them and at the bottom. To determine absolutely the best form for each description of clay to be cut would involve numerous and costly experiments which have not as yet been made.—**J. A. Apjohn,** *Proc. Inst. C.E., Vol. CLIV., Eng. Conf., Sec. 11, June, 1903.*

Self-Supporting Steel Stacks.

IN the recent design of several large self-supporting steel stacks, the writer had occasion to develop formulas which would give a simple solution for rivet spacing in the horizontal joints. These formulas are also capable of application for solving the strains in the anchor rods of all similar structures. As the bending moment (M) in inch pounds, at any horizontal section, due to wind pressure $= 6PL^2$, the stress per circumferential inch of section (K), $= \frac{6P}{A} L^2$, where P = pressure per vertical foot of stack, $A = \pi R^2$ (R = radius of section in inches), and L = distance in feet from top of stack to the section. Adding to K, the proportionate dead load for weight of structure above this section, and dividing the value of one rivet by this sum, gives the required spacing in inches. *Anchor Strains.*—If the area of the circle on which the anchor rods are located be used for A, in the equation $K_{max} = \frac{M}{A}$, the value of K, so obtained, will be the imaginary strain on one circumferential inch of such circle, and this value multiplied by the length of arc between anchors will give an approximate result for the total wind reaction on one rod. If the exact figure is desired, the value of K, for each inch of this length of arc, may be computed from the proportion, $Ky : K_{max} = y : R$, where y = perpendicular distance in inches of any point in section from neutral axis, the values of y being obtained by scale; and the summation of these values will be the exact wind reaction. If W = total dead load, and N = number of anchor rods, the net maximum reactions

will be $(W \div A)$ + wind reaction.—**R. E. Newton,** *Eng. Rec., Vol. XLVII, No. 23, June 6, 1903,* p. 599-600.

Types and Details of Bridge Construction.

ARTICLE No. VIII. of this series contains descriptions and drawings of the Padern Viaduct over the Adda, Italy; the Eads Bridge across the Mississippi River, at St. Louis; and the Kaiser Wilhelm Bridge across the Wupper River at Muengsten.—**F. W. Skinner,** *Eng. Rec., Vol. XLVII., No. 23,* pp. 600-603.

METALLURGY.

The Production of Open-Hearth Steel from Blast-Furnace Metal.

THREE years ago the author introduced a method of steel-making which gives a rapidity of conversion far in advance of ordinary open-hearth practice. This method, known as the continuous process, derives its name from the fact that the furnace is worked continuously during an entire week, or longer period, without completely emptying it. An ordinary fixed furnace, with two tap-holes at different levels, might possibly be used, but the process is more conveniently worked in tilting furnaces of large dimensions. The lining should be of basic material, for the heat being continuous would probably be too severe for a sand lining to withstand successfully. In practical working the process is carried out as follows: On Sunday evening the furnace is charged with a mixture of scrap and solid pig-iron or partly solid pig-iron and molten pig metal. This "filling charge" is worked down in the usual way until a bath of finished steel is obtained which, with a furnace of from 75 to 100 tons capacity, will take about 12 hours. When ready for tapping the furnace is tilted and a definite part of the charge is run out into a steel ladle in the ordinary way, the necessary ferro additions being made to the ladle as the metal runs in. The amount of ferro-manganese required is less than that customary in ordinary practice, and from present experience is found to be on an average from 10 lbs. to 12 lbs. per ton of steel made. After the metal is cast the furnace is turned back into the upright position, the tap-hole lightly closed, and any necessary repairs to the lining effected. A certain amount of lime and oxide of iron is added to form a slag, with which to oxidise the metalloids of the incoming pig metal. After these additions are incorporated with the fluid slag further additions of molten pig metal are made to the steel remaining in the furnace. The reaction between the slag covering of the bath and the molten metal introduced results in the immediate oxidation of the metalloids of the pig iron. Silicon, carbon, and phosphorus are rapidly removed, although it may be noted that when the silicon is high the carbon removal does not take place at once; hence it is preferred that the pig iron added should be low in silicon. The combustion of the carbon in the form of carbonic oxide materially diminishes the amount of fuel per ton of steel, and the removal of the metalloids by the oxides contained in the ferruginous slag results in the precipitation of iron from the slag into the bath, so that the yield obtained by this process is greater than that obtained by the ordinary pig and scrap open hearth process. After the first reaction has subsided the bath is sampled and worked down until it again represents finished steel. Another definite amount is then cast, and the process continued through the work. On Saturdays the furnace is emptied at short intervals, and any necessary repairs made. The weekly output varies with the size of the furnace and the quality of the pig metal used. In the States a 200-ton furnace working on hematite iron has yielded 1,400 tons of steel in the week. At Pencoyd, using a 70-ton furnace, more than 750 tons of steel have been made in the week from pig iron containing 0·8 per cent. phosphorus. At Frodingham, with a furnace of 100 tons capacity more than 600 tons have been obtained in the week, using pig iron containing nearly 2 per cent. phosphorus.—**B. Talbot,** *Sect. 4, Eng. Conf., June, 1903, Vol. CLIV*; *Proc. Inst. C.E.*—*P. L.*

Alloys of Iron, Nickel, and Manganese.

THE author has previously shown that manganese, to the extent of about 5 per cent. alloyed with 94 per cent. iron and 0·45 to 0·50 per cent. carbon, gives a most brittle product. So brittle was this material in its cast state that specimens of it could be readily powdered under comparatively slight pressure. In spite of this extreme brittleness the alloy could, when heated, be readily forged, this treatment increasing the tenacity but still leaving the alloy exceedingly brittle, as shown in Table I. on the opposite page. The material was not susceptible to improvement by any of the toughening methods generally employed. In a somewhat similar manner an alloy of iron with 15 per cent. nickel is brittle, although less so than the foregoing manganese alloy. The results obtained from this nickel alloy are shown in Table II. Whilst the tenacity of this alloy is much greater than that of the 5-per-cent manganese alloy, the material, whether in the annealed

TABLE I.

Analysis.					Treatment.	Elastic Limit. Tons.	Tensile Strength. Tons.	Elongation % on 8".	Reduction of Area. %
C.	Si.	S.	P.	Mn.					
0·52	0·37	0·07	0·08	6·95	Forged into test bar	—	25·43	1 50	—

TABLE II.

Analysis.						Treatment.	Elastic Limit. Tons.	Tensile Strength. Tons.	Elongation % on 2".	Reduction of Area. %
C.	Si.	S.	P.	Mn.	Ni.					
0·23	0·24	0·11	0·05	0·93	15·48	Unannealed	50·55	94·00	3·25	2·48
						Annealed...	Bar crack'd	68·00	1 15	0·74

TABLE III.

Mark.	Analysis.				Treatment.	Elastic Limit Tons.	Tensile Strength Tons.	Elongation % on 2"	Reduction of Area %
	C.	Si.	Mn.	Ni.					
1109 D	0·60	0·84	5·04	14·55	Bar as rolled ...	27	54	45	38
,, ,,	,,	,,	,,	,,	Unannealed, not toughened	25	56	68	44
,, ,,	,,	,,	,,	,,	Heated to about 1100° C. and quenched in cold water ...	18	50	75	47
3417 F	,,	,	,,	,,	As forged.	27	55	32*	42
3418 F	,,	,,	,,	,,	Heated to about 1100° C. and quenched in cold water. ...	20	51	57*	52

* on 8".

or unannealed state, was extremely fragile under ordinary bending tests. The author has, however, found that a double combination of the two metals in question, with iron in exactly the same percentages as before, gives a most tenacious alloy. Results obtained from tests of the forged material are given in Table III. above. The elongation takes place over almost the whole length of the bar under stress. In the form of hard-drawn wire of 15 B.W.G. the tensile strength reached 122 tons per sq. in., and the material then withstood only three torsions and five bends. The alloy submitted to the Frémont drop test gave the exceedingly high value of 35 kg. metres, the specimens bending double and remaining unbroken. The size of the specimens was 30 mm. by 8 mm. by 10 mm., nickled 1 mm. in width and 1 mm. in depth. As the very best mild steel will not stand more than about 20 kg. metres, and generally breaks, it will be seen what remarkable toughness this alloy of nickel and manganese with iron possesses. When tested in the ordinary way its magnetic susceptibility is very slight, and its electrical resistance is enormous, namely 80 to 84 microhms—that is, about six times that of ordinary iron—with a temperature coefficient of 0·1092.—**R. A. Hadfield,** *M.Inst.C.E., Sec. IV., Eng. Conf., June 1903, Proc. Inst.C.E., Vol. CLIV.—P. L.*

The Heat Treatment of Steel under conditions of Steelworks Practice.

RESULTS obtained on small samples are very different to those arrived at in actual practice when large masses of steel are subjected to similar heat treatment. The author therefore decided to investigate heat treatment under actual works conditions. With this object in view a number of round bars, varying in size from 1½ ins. to 6 ins. diameter, and in carbon content from 0·20 to 0·65 per cent., have been heated to different temperatures for various lengths of time. The bars after treatment have been subjected to as complete a set of mechanical and other tests as possible, to determine the influence of the particular treatment on the strength, ductility, and general physical properties. The general conclusions to be drawn from the results may be thus summarised :—Small sections of rolled steel containing 0·20 per cent. carbon can be heated within wide limits without seriously affecting resistance to impact, but 850 degs. Cent. is the maximum temperature to which such material should be heated, and slow cooling tends to produce brittleness. For larger rolled sections containing 0·20 per cent. carbon 800 degs. Cent. is the maximum temperature. Forged bars of the same steel should not be heated beyond 850 degs. Cent. Between 500—600 degs. Cent. brittleness is produced in a marked degree, especially if followed by slow cooling. The best temperature at which to treat such material is 800 degs. Cent. Small sections of rolled steel containing 0·30 to 0·40 per cent. of carbon are improved in shock-resisting qualities when heated to 650—800 degs. Cent., whether followed by slow or rapid cooling. Heating between 500 and 600 degs. Cent. does not produce brittleness as in 0·20 carbon steel. Large rolled bars give the best results after heating to 700—800 degs. Cent. with the maximum resistance at 760 degs. Cent. When heated at 900 degs. Cent. and higher, a pronounced brittleness develops. Slow cooling does not seem to be very injurious. Steel containing 0·50—0·60 per cent. carbon, in small and large rolled sections, appears to be in its toughest and strongest condition after being heated to 700—800 degs. Cent., and followed by either slow or rapid cooling. Forged bars require to be heated to a slightly lower temperature than rolled bars. Steel containing between 0·60 and 0·70 per cent. of carbon in small rolled sections possesses greatest ductility and resistance to sudden shock after being heated to 600—700 degs. Cent. The 4-in. rolled bars of this steel give the best drop-test results at about 720 degs. Cent. The rate of cooling apparently does not very much influence the results. Forged bars of 6 ins. diameter give the best result under the falling weight test after being heated to 700—760 degs. Cent., and followed by either rapid or slow cooling. Heating this grade of steel in large bars to temperatures of over 850 degs. Cent. produces brittleness, which is very marked if the temperature exceeds 900 degs. Cent.—**A. Campion.** *Jnl. Iron and Steel Inst., May, 1903.*

The New Works of the Lackawana Steel Company.

THIS article describes the works of the Lackawana Steel Company, now in course of erection at Stony Point on the shore of Lake Erie, near Buffalo. The chief advantages of the situation are a deep water front, accessible for the largest Lake steamers, abundant and pure water supply from the Lake, navigation over the whole system of the Great Lakes, and through the Welland Canal and St. Lawrence River to the Atlantic. Navigation is also offered by means of the Erie Canal, having 10 ft. of water, directly to the Hudson River and New York. The works have also direct connection with twenty-seven large railway systems. The chief feature of the design is that every process of steel manufacture, from the treatment of the raw ore to the delivery of the finished product, may be conducted in logical sequence; to this end the whole of the different installations for the main processes are grouped in comparatively long and narrow areas parallel to each other, and to a ship canal leading from the Lake. These groups are served by many connected lines of longitudinal and belt tracks, materials move continuously in transverse or longitudinal directions, and are transferred from one division to another by surface lines of railroad. The scale of operations is shown by the following separate departments into which the plant will be divided :

1. 940 bye product coke ovens. Capacity 4,000 tons per day.
2. Ore unloading department provided with five Hulett unloading machines and three Wellman-Seaver reloading machines.
3. A present installation of two 300-ton and four 800-ton blast furnaces with provision for a future extension to a capacity of about 7,000 tons daily.
4. Four 10-ton Bessemer converters, two rail mills, a billet mill and splice bar, and structural mill, the capacity of the whole being about 3,000 tons daily.
5. Six 200-ton Talbot open-hearth steel furnaces, a structural mill, a sheared plate mill, and a universal plate rolling mill, having a total capacity of about 1,650 tons per day.
6. The power department, including a central station for electric power, compressed air, and hydraulic power, a pumping plant for all water supplies, blowing engine houses, boiler houses, and gas producers.
7. Repair and construction shops.

8. Yard department controlling tracks and operating all locomotives.
9. The terminal and connecting railroad department which receives all materials except ore and delivers the finished products to outside roads for shipment.
10. The house department, including two villages, one with 454 houses in rows for the workmen, and another with 100 detached houses for the foremen and clerks.
11. The administration department, where all designing, construction, and operation is controlled.

Anon., *Eng. Record, May 30, 1903,* pp. 568-571.—*P. L.*

The Dangerous Crystallisation of Mild Steel and Wrought Iron.

THE term brittle crystallisation has led to some confusion, and the author suggests the recognition of two types of brittleness. First, actual or mechanical brittleness, which causes the metal to snap on any attempt being made to bend it. Second, potential or vibratory brittleness, in which condition the metal gives excellent tests, will readily bend double without fracture, but is, nevertheless, very liable to fracture suddenly under vibration or alternation of stress at a stress far below its elastic limit. Steel possessing the latter type of brittleness, when examined microscopically, usually presents a coarse structure showing sharply-defined junction lines of the ferrite and pearlite crystals, whilst in form the constituents are sharply angular. Usually, however, the indications of the microscope possess only the melancholy interest of a post-mortem examination. To detect vibratory brittleness the author has devised a modification of the alternating stress or fatigue test. Test pieces $\frac{3}{8}$ in. square by $5\frac{1}{2}$ ins. long are gripped in a die, 4 ins. of the piece projecting. The end of the test piece is received in a slotted angle-bar, which is attached to a slide making about 100 strokes per minute. The slot allows the test piece to be deflected $\frac{1}{8}$ in. on either side of the centre, the test piece thus receiving about 200 blows per minute. A steel known to possess vibratory brittleness, but which, nevertheless, will in the cold state bend double and will elongate 30 per cent. on a length of 2 ins. under a maximum stress of 30 tons per sq. in., will, when submitted to the test just described, be found to snap after receiving about 200 blows. On the other hand, a steel little liable to fracture under vibration has a time endurance of about two minutes, equivalent to 400 blows. *Heat Treatment of Mechanically Brittle Steel.*—Stead has shown that the coarse structure of mechanically brittle steel is made much finer by heating to slightly over 900 degs. C., but although the structure is fined down by such treatment, the operation does not produce satisfactory normal crystallisation. Experience shows that crystallisation so coarse as to produce mechanical brittleness can be thoroughly removed only by hot working or, better still, by consignment to the scrap-heap for re-melting.—**Prof. J. O. Arnold,** *Sect. IV., Eng. Conf., June, 1903, Vol. CLIV., Proc. Inst. C.E.—P. L.*

The Equalisation of Hot Blast Temperature for Blast Furnaces.

IRREGULARITY of any kind in blast furnace practice gives a corresponding irregularity in the quality of the product. One source of irregular working is found in the variable temperature of the blast which, when heated in the usual type of reversing regenerative stove, varies some 200° Fahr. to 300° Fahr. The effect of this variation is to alter the position of the melting zone of the furnace, resulting in extreme cases in "scaffolds," which cause the furnace to hang and produce iron of low quality and reduced quantity until the scaffold is fused off. Constantly uniform temperature of the blast, with practically no loss of heat, may be obtained by interposing in the course of the blast between the stoves and the furnace a mass of firebrick chequer work, which takes up heat from the blast when it is above the average, and gives heat back to it when its temperature is below the average. This apparatus, known as an equaliser, consists of a steel shell lined with brick and filled with firebrick chequer work. It is divided centrally by a wall forming two chambers communicating at the top, whilst between the brick lining and the shell a non-conducting layer of slag wool is interposed. The hot blast from the stoves passes up one chamber of the equaliser, down the other, and out at the bottom through mains to the furnace. When the blast comes from a freshly-heated stove, and consequently of high temperature, heat is absorbed by the brickwork of the equaliser; but as the stove's run continues the temperature of the blast gradually falls until it is below that of the equaliser, and the chequer work then returns heat to the blast passing over it. In this way there is a constant exchange of heat between the blast and the chequer work, resulting in blast of uniform temperature passing to the furnace at practically the average of that at which it enters the equaliser. The equaliser has no valves, requires no attention, and as gas does not pass through it, no cleaning is required. Its effect in producing blast of a uniform temperature may be compared to the action of a fly-wheel in producing regular speed in an engine.—**J. H. Harrison, M.Inst.C.E.,** *Sect. IV., Eng. Confce., June, 1903, Vol. CLIV., Proc. Inst. C.E.—P. L.*

Ingot-Iron in Naval Construction.

THE author discusses the influence of cold shocks on the properties of ingot-iron. He had noticed that in repairing an iron ship, which had become damaged by very cold weather and heavy drift-ice, some fissures were produced in plates that otherwise did not show any sign of being injured. This fact, in connection with the consideration that the same ship, in spite of rather rough treatment, should have served more than ten years in the Hamburg harbour without any plate being broken, induced the author to presume that the strain in the plates did not exist before the ship became damaged. This hypothesis is confirmed by the fissures showing a behaviour characteristic of extreme hardness. On bending tests being made with strips of the plate, rupture occurred outside the bending line, proving the presence of strain. In fact, specimens behaved as such a hard material that drilling or riveting would have been absolutely impossible, if they had possessed the same hardness before; nor would they have been able to remain undamaged for years in the most exposed parts of such a ship. The only hypothesis left is therefore that the structure of the iron, having undergone a modification, the metal had lost its ductility and softness, this alteration in the properties being due to heavy shocks received during violent cold. A further confirmation of these views is afforded by the fact that deep bosses of older date were to be found in the immediate neighbourhood of the fissures, proving great hardness. If the iron at time of origin of these bosses had been as hard, fissures would most surely have occurred at that time.—**L. Benjamin,** *Stahl und Eisen, XXIII., No. 11*, p. 703.—*A. G.*

An Interesting Melting Equipment.

THE economical handling of cupola stock and molten iron is one of the problems of large foundry management, and one which the Atlas Engine Works, Indianapolis, are attempting to solve by concentrating all melting operations at one point, from which the molten iron may be delivered to their three foundries. A melting house has been planned to hold six cupolas, and owing to the crowded nature of the ground-space, this house is located about a quarter of a mile away from the foundries. The furnace charges are made up in self-dumping cars, which, after passing over the yard scales will, by gravity, descend a track leading to an inclined plane, where an electric hoist and endless chain belt will furnish an automatic elevating apparatus for placing the cars on the cupola stage. After discharging its contents into one of the cupolas, the car passes on to the end of the melting house, and is returned to the stock-yard for refilling. The molten metal is conveyed from the cupola spouts to the foundries in Whiting geared truck-ladles of 10 tons capacity, and it is expected that when all is in working order, a ladleful of iron will reach its destination in under five minutes.—*The Foundry, June, 1903*, pp. 154-156.—*P. L.*

Foundry Management.

IN this article the author reviews the backward condition of the average American jobbing foundry, quoting typical instances showing the poor facilities they possess, and the erratic nature of their management. These foundries compare very adversely with the speciality ones, in which moulding and melting practice have reached a very high state of efficiency. To bring the jobbing foundries into line with the speciality shops, more attention must be paid to the organisation and modern facilities adopted, by which the moulders may be employed in actual moulding the greater part of the day. Cupolas and charging platforms offer a further wide field for improvement, the charges of iron and coke having in many cases to undergo three or more successive handlings before reaching the charging stage. The most satisfactory solution of the "foreman problem" is found in dividing the foundry into sections devoted to one class of work, and under the charge of a sectional foreman. The sectional foremen are in turn under the direct control of the general foundry foremen.—**Edward Kirk.** *The Foundry, June, 1903*, pp. 167-173.—*P. L.*

Iron in Railway Constructions.

THE author discusses the properties required in rail materials, it being stated that a strength not inferior to 70 kgs. per square millimetre is necessary, whereas cross-sleepers might be made of milder ingot iron of a strength of from 40 kgs. to 50 kgs. The importance of hardness in connection with wear and tear is emphasised, it being shown that Bessemer steel is the most suitable in this respect. The most serious drawback is found to be in the construction of the joints; the author has designed a special form of the latter, eliminating its prejudicial influence on the life of the rail. Much remains to be done for the improvement in the design of rails, this being a problem of great bearing on the development of civilisation.—**Dr. A. Haarmann,** *Stahl und Eisen, XXIII., No. 12, June 15, 1903* (*Paper read before the Berlin Congress for Applied Chemistry*).—*A. G.*

Determining the Percentage of Oxygen in Ingot-Iron and Steel.

OXYGEN present in ingot-iron is prejudicial, particularly in the harder qualities, a percentage higher than 0·15 per cent. being even fatal in rolling. This is frequently ascribed to sulphur, the more so as pig iron, with low percentages of manganese, is often rich in sulphur. That ingot-iron should be so sensitive to sulphur is probably due to the increase of the influence of oxygen with augmenting hardness. It would, therefore, be most desirable to find out some adequate method of determining the percentage of oxygen. The usual method, consisting in heating the specimen in a stream of dry hydrogen, besides being inadequate, does not permit of stating the amount of oxygen existing in combination with manganese, silicon, and aluminium.—**F. Lurmann, Jr.,** *Stahl und Eisen, XXIII., No. 12, June 15, 1903 (Paper read before the Fifth International Congress for Applied Chemistry, Berlin).—A. G.*

Determining the Percentage of Manganese in Steel.

THE main advantage of the presence of manganese in hard steels is the great strength imparted to them, in connection with a convenient ductility, a result impossible in the case of carbon being alone present. The limits of elasticity and resistance to tension are increased, and the conditions of tempering improved. As, however, beyond 1 per cent. of manganese steel becomes brittle, it is important to know a rapid and accurate method for determining the percentage of manganese. The process suggested by the author is based on the following reaction. If a manganese salt be heated with nitric acid and lead bioxide, a purple colouration is obtained, owing to the formation of permanganese acid.—**J. Mallette,** *La Revue Technique, XXVIII., No. 11*, pp. 327–328, *June 10, 1903.—A.G.*

PRIME MOVERS.

Internal-Combustion Engines for Dynamos.

SINGLE-CYLINDER single-acting gas-engines, although made in large powers, would not usually be chosen in large units for dynamo-driving, except where regularity is not important. Although the *vis-à-vis* type has done excellent service, and is now in use for driving alternators in parallel on a large scale, little need be said about it in face of the change to the double-acting type which is taking place. Another type is being made by Körting Bros., of Hanover, who get about 300 h.p. to 400 h.p. out of each cylinder, the two cranks being placed at 180 degs. This type is going to be largely adopted, but the tandem-engine, with its straight line stresses and equally timed impulses, is likely to live longer than the *vis-à-vis* type or the twin-cylinder type. The Premier engine is an example of the straight-line type. The double-tandem engine can be carried to very large powers, and makes a simple and strong engine, but it is heavy for its work and covers a large floor space. Very good work has, however, been obtained from this engine, and it is suitable for driving alternators in parallel up to units of 2,500 h.p. Quite a number of firms now manufacture vertical gas-engines with two, three, or four cylinders, all of them constructed specially for dynamo driving. Many attempts were made to get over the difficulty of a piston-rod stuffing-box. The solution of the problem has, however, come gradually, and numerous makers have now examples of efficient stuffing-boxes fitted in the closed ends of gas-engine cylinders, and giving no trouble. All the leading makers now construct double-acting engines, in which type powers of 1,000 h.p. with single-cylinder engines, and of 4,000 h.p. with double-tandem engines, are readily obtainable. Nearly all the important orders which are now being placed for large gas-engines are for the double-acting type. The Körting gas-engine gives two impulses in one cylinder per revolution, being in this respect like an ordinary steam-engine. Many firms have taken out licences to build this engine, and in this country it is made by Messrs. Mather & Platt, and by Messrs Fraser & Chalmers. Brief mention must be made of the Vogt gas-engine, which, like the Körting engine, gives two impulses per revolution in one cylinder. It is unique, in that the explosions take place over water, and the motor-cylinder is filled with this fluid. This engine embodies the principle of internal cooling, so that water jackets are dispensed with, and the metal cylinder may be made as thick as strength requires for any size of cylinder. The term "internal combustion engines," embraces oil engines, but oil engines above 200 h.p. are rare, and cannot compete in cost of fuel with gas-engines using cheap producer-gas, especially when the system of recovering the ammonia from the coal is available. In general, a gas-engine, giving at least one impulse per revolution, is necessary for all central station direct-coupled dynamo-sets; and in cases of alternators working in parallel, engines should be chosen which give two impulses per revolution.—**H. A. Humphrey,** *Proc. Inst. C.E., Vol. CLIV., Eng. Conf., Sec. III., June, 1903.*

How to prevent boiler explosions.

WHEN a boiler explodes by failure of the bottom plates it indicates an overheating of the plates over the fire by reason of low water or scale. For the first cause the remedy is the use of low-water alarms or automatic feed-water regulators. The low-water alarms either blow a whistle or open a blow-off valve to relieve the boiler of pressure when the water in the boiler becomes lower than normal, and the automatic feed regulators will feed the boiler when the water level falls. These devices are also arranged to indicate high water as well as low, and are a valuable check or reminder to the water tender. For the second cause, the remedy is periodically to clean the boilers and remove the scale, the frequency of this operation being dependent upon the quantity of incrusting salts contained in the feed water. Fusible safety plugs of tin and lead alloys are a supposed protection from the effects of low water; but in actual practice they are, in general, failures, for the reason that they are protected from the heat by the accumulation of soot and dirt on the side towards the fire, and, moreover, a higher temperature is required to melt them after continued exposure to heat. The omission of fusible plugs is not advocated, but they should be properly set in the boiler and frequently inspected and cleaned and occasionally renewed to insure proper action. Low water in boilers is often due to imperfect gauges and neglect of use of gauge cocks. Low water is also frequently due to defective blow-off cocks, or to negligence on the part of the firemen in not entirely closing the cocks after blowing off a boiler. As a protection against high pressure, boilers are provided with safety pop valves, which should be set to blow off when pressure rises five pounds above normal boiler pressure. Pop valves should have ample outlet area, and should be tried and inspected daily to prevent the valves sticking to the valve seats, and rendering them inoperative. In general, all boiler explosions which are not the result of overheating of the crown plates from low water or scale are caused by weak longitudinal riveted seams. Proper workmanship, which will add 15 to 20 per cent. to the strength of the boiler at practically the same cost, can be secured when the boiler is purchased under proper specifications, and the shop work is under the inspection of the purchaser's engineer. When boilers of proper construction are installed, equipped with automatic safety fittings, and given the periodical inspection of a boiler insurance company and competent attendance, the danger from explosion is remote.—**R. L. Gifford,** *Mod. Machy., Vol. XIII., No. 5,* pp. 139–147.

Superheated Steam and Locomotives.

THE author deals with the question why the application of superheated steam in locomotives has been less successful than with stationary engines. Among the factors responsible for the difference, there are the different calorific values of saturated and superheated steams, from the physical point of view; as, however, the specific heat of superheated steam is but imperfectly known, it is so far impossible to account for this. It may be inferred from Brückmann's data that a somewhat reliable determination of the heat and coal saving by superheating, as due to the locomotive itself, is not possible without an accurate knowledge of the composition of the steam generated in the locomotive boiler. The same is true of the differences in the utilisation of heat in producing the steam. It is further shown, by some experiments undertaken by the author, that the coal saving of the hot steam locomotive is by no means independent of the work performed by the same. Gauging the specific efficiencies of hot and wet steam boilers respectively on the co-efficient of vaporisation will lead to undervaluing very much the former class of boilers, as no account is taken of the amount of heat communicated to the superheater. The following conclusions are drawn from an attempt to calculate the thermic permeability for the conditions present in locomotive superheaters:—On account of the influence exerted by the percentage of water, valuable data will be obtained only in the case of the state of the boiler steam being accurately known. The errors due to neglecting this influence will be the greater, as the amount of heat supplied to the superheater is smaller. Both the permeability and percentage of water will, in the opinion of the author, be given with a fair accuracy by accurate temperature and water measurements. It seems that the thermic permeability is variable to a great extent along with the velocity of the steam, for velocities ranging between 10 and 14 metres per second. The author next discusses the *rôle* of the relative positions of the heating surfaces of the boiler and superheater, according as the latter is either connected to the boiler, so as to have the superheating effected only by *part* of the amount of smoke-gases at a very high temperature, or to the heating surface of the boiler, so that the steam is superheated at a low temperature by the *total* amount of smoke-gases, it being shown that the former

arrangement is much more advantageous as regards the boiler weight, provided the efficiency of locomotives be not capable of being further increased.—**O. Berner,** *Zeitschr. Ver-Deutscher Ingen.—A. G.*

Collapses of Furnace Crowns.

LET it be granted that the fire side of the plate is hotter than the water side, and that the temperature is a shade higher near the centre line than elsewhere. If the crown-plate were a free strip of metal, as indicated by Fig. 1, this distribution of heat would cause it to change its form from that shown by the full lines to such a one as is indicated by the dotted lines, owing to the greater expansion of the layers on the fire side. But the resistances prevent the sides moving out to anything like the distance due to the difference in the expansion of the two faces of the plate, and the result is that the inner layers are crushed up to some extent, the outer ones being at the same time possibly stretched to some minute extent, but the marked effect is the crushing. Assuming now that the layers next the fire have been more or less crushed in this way, suppose, further, that the furnace temperature falls. Then, if the crown-plate were free, it would tend to return to its original form; but, owing to the crushed and shortened inner layers, it would go further and become an oval, with the longer diameter vertical, if it were allowed to become quite cool again. But the crown-plate is restrained, and it probably does not even return to its original semi-cylindrical form when cooled. Thus the crushed layers on the fire side are trying to pull in the sides of the furnace and the resistances are preventing more than a partial readjustment of form, with the result that the crushed layers are in a state of tension and the layers next the water are in compression. Now, if stresses, as above described, act in every element of the furnace crown (their disposition being that indicated in Fig. 2), their general tendency is evidently to straighten the curvature and eventually to produce a minute flat at some point. In the case of the furnace crown the minute flat will evidently tend to appear at the hottest point in the circumference—the top. Let the full line in Fig. 3 represent such a flat after the cumulative effect of the forces has made it quite perceptible. Then it appears that there are two weak points at the angles *A*, *A*, where the crushing effect of compressive stress would be localised, with the result that the section would tend to gradually take the form indicated by the dotted lines. It would follow, if this is the real cause of these gradual collapses, that they will be less

FIG. 1.

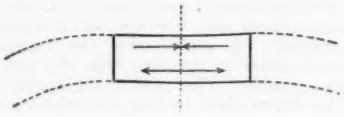


FIG. 2.

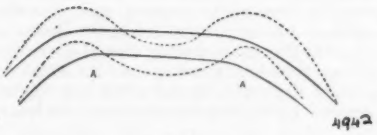


FIG. 3.

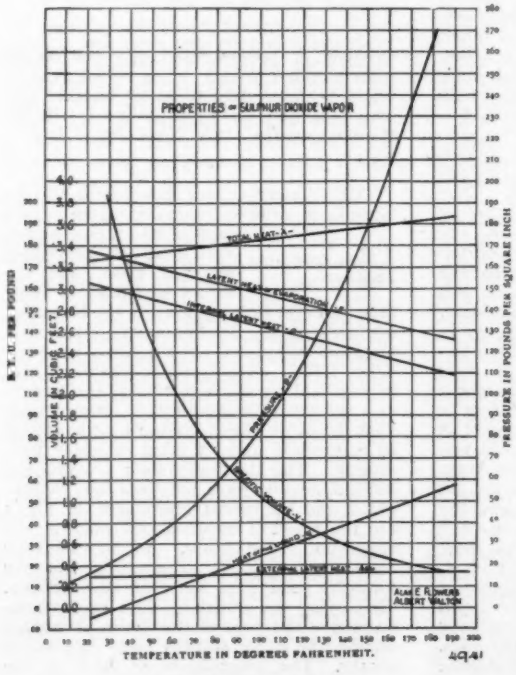
COLLAPSE OF FURNACE CROWNS.

frequent in boilers fitted with mechanical stokers, other things being equal, and it would be interesting to know whether any such difference has been observed.—**H. M. Rounthwaite,** *Proc. Inst. Nav. Archts., 1903.*

The Sulphur-Dioxide Engine.

THE "binary vapour heat engine," in its latest form, exhibits more clearly the advantages of the system than any such apparatus previously reported upon, and the record produced is lower than was ever before known in the history of the heat-engine. Its minimum consumption of steam is 8·36 lbs. per h.p. hour, less than 9,500 B.T.U. The question whether it will be practically possible to employ this system as a commercial and profitable improvement upon the single-vapour engine must be settled by experience under a great variety of conditions. The thermodynamic properties of sulphur dioxide have not been fully investigated, and the curves reproduced in Fig. 1 are the result of computations made at the suggestion of the author. All the values are based on Regnault's experiments, but the formulas used were those of later writers. Employing the calculated data in the comparison of the work of the Berlin secondary engine, the writer secures some interesting results. The expenditure of heat in the secondary cycle averages, for the ideal case,

about 20,000 B.T.U. per i.h.p. hour, not a remarkably low figure; but, on the other hand, it costs nothing, as it is supplied by the waste of the primary element of the combination. The quantity of SO_2 per i.h.p. hour for unity efficiency, under the conditions of its employment in this case, is a trifle above 600 lbs.; but this amount is unimportant, as this is a circulatory system, and once the charge is received into the system it costs nothing, except for renewal or leakage. The quantity demanded for the actual efficiency is about 130 lbs., and the same remark applies. The piston displacement per i.h.p. hour is about 220 cub. ft., and this will vary with the mean effective pressure on the piston. The same figure, reduced to expenditure per minute, becomes about 3·66. The weight of steam entering the secondary element per i.h.p. hour averages a little more than 20 lbs. Comparing these figures with those of the trials, it is found that about one-half of the supply to the secondary engine is wasted by extra-thermodynamic methods of rejection. It is, however, sufficiently evident that the main source of the gain observed is the securing of high absolute pressures and of large mean effective pressures, with relatively small variation of volumes, at a part of the thermal range at which steam does not give pressures of sufficient magnitude to permit the maintenance of satisfactory mechanical efficiency.—**Professor R. H. Thurston,** *Jnl. Franklin Inst., Vol. CLV., No. 6,* pp. 429-442.



THE SULPHUR-DIOXIDE ENGINE.

Marine Engine Design.

In reviewing the field of marine engineering at the present date, the most comprehensive grasp of the situation is obtained by arranging an analysis according to a quantitative function of the engine performances, which has invariably increased with the successive problems solved during the last fifty years, viz.: piston speed. Piston speed commended itself from the first to observant marine engineers as the most economical of all methods of increasing power, and over the whole period there has been a steady growth in this respect, as evidenced by the curves in Fig. 1. Leaving out of consideration some very small or very special craft, such as launches, small coasters, tenders, and tugs, there are seven main classes of service for which the marine engineer has to design appropriate propelling machinery, and within each of which he has to attain increase of power with reduction of unit weight in the case of the faster vessels in the group. These services are: 1. Side-wheelers; 2. Freighters; 3. Freight and passengers; 4. Passengers and mails; 5. Channel and sound express boats; 6. Battleships and cruisers; 7. Torpedo-boat destroyers and scouts. The machinery particulars of such craft have been graded in tables, given by the writer, according to piston speed, and a glance at the data will show how systematically the designer has resorted to a higher rate of working when called upon to supply greater power with reduced unit weight. The seven classes mentioned embrace the great bulk of the marine designer's work with reciprocating machinery, but the practicability

of the marine steam-turbine has considerably altered the engineering outlook. The new prime-mover is fully as flexible for varying conditions as the older, and we may soon expect to see the turbine installed on the larger fast craft of both services—**J. Calder,** *Marine Engg., Vol. VIII., No. 6,* pp. 312-315.

Escape of Saturated Water Vapour.

THIS paper was undertaken with a view to reduce the equations relative to the escape of wet steam to a simpler form, so as to afford a better idea of the different processes, and to make practical calculations on complicated problems as to the escape of steam possible.—**W. Schule,** *Dingler's Polytech. Jnl., Vol. CCCXVIII.,* pp. 355-358, 369-372, 388-392, *June, 1903.—A.G.*

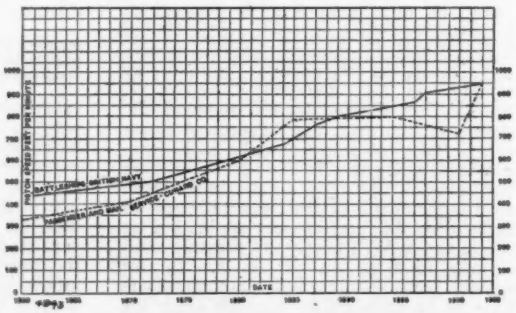
Superheated Steam.

MANY important experimental data are recorded, the conclusions drawn from them being as follows:—(1) The use of superheated steam results in an improvement of the efficiency of steam-engines of any type, even though they be steam-jacketed. (2) The improvement increases with the degree of superheating. (3) The consumption per unit of work remains constant both at full and half load.—**A. Witz,** *L'Eclairage Electrique, XXXV., No. 26, June 20th, 1903,* pp. 441-455.—*A. G.*

TRACTION.

Design of Permanent Way and Locomotives for High Speeds.

THE keynote of the paper itself, and the discussion which followed, was set forth by the author in divided form as follows:—(1) The condition of the permanent way itself; and (2) the design of the locomotive. After pointing out that the impact on permanent way necessarily arises from these two sources, it is stated that the increase in train mileage, at any rate on British railways, is mostly on long-distance traffic. This generally means heavy trains and heavy axle-loads, hauled at relatively high speed. The strength of the permanent way and the condition of the road-bed are of the first importance; as, when the permanent way is of a relatively light structure, or the road improperly packed and badly drained, there can be no satisfactory running at high speed. Indeed, with the increase in high-speed traffic there comes a more imperative necessity to give greater attention to these matters, as well as to the alignment of the lines and the super-elevation of the outer rail in curves than heretofore. The next point is equally important—viz. the maintenance of a standard gauge width. The author has had instances of new road laid in straight line where the sleeper had not been adzed, and the chairing had been done by hand, and it was found that the gauge varied to the extent of $\frac{1}{8}$ in. to $\frac{3}{16}$ in. Although the permanent way was of heavy section, the joints good, and the packing and ballasting properly done, the running was not satisfactory; so much so that the whole length so laid was regauged, and the traffic again sent over it at high speed with the result that the engines and carriages ran comparatively quite smoothly. Reduction of impact at switches and crossings and smooth-running through junctions are largely brought about by attention to the following points:—(1) Making curves of easy radii; (2) using long switches at diverging and converging points and avoiding short rails; (3) working to a uniform gauge and giving special attention to levels; (4) restricting the speed on curves. On lines with expresses running up to 60 miles per hour no curves should be of less than 40 chains radius. At least the length of a train—say 700 ft.—should, in his opinion, be secured on the straight line between reverse curves where possible. All who are connected with railways know only too well that some types of locomotives, when driven at high speed, oscillate laterally and vertically to a dangerous extent, even on a good road, and that the only way to obviate this is to reduce the speed. Locomotives having four wheels coupled in front and a bogie under the footplate—4.4 American notation—are a specially undesirable class to be run at



CURVE OF PISTON SPEEDS DURING THE LAST FORTY-THREE YEARS

high speed. In proof of this may be cited the Doublebois accident on the Cornwall railway on May 13th, 1895, in which two such locomotives of a fast passenger train left a practically new bull-headed road having easy curves, due to the type of locomotive in use. Engines with single driving-wheels, and only one axle in front with one behind, are likewise unsatisfactory, and plunge considerably at high speeds, even on good roads; and there can be no doubt that the introduction of the leading bogie, giving a longer wheel-base, is the greatest improvement in this respect which has yet been carried out. One advantage of the four-wheel coupled engine over the single at high speed is the fact that the counter-balancing can be spread over four wheels in place of two. No doubt this is the principal reason that it is so difficult to build a single driving locomotive, even with a bogie in front, to run smoothly. Although locomotives with a high centre of gravity are, theoretically, first-class machines, if running on a perfect road, the practice of so building them has its limit; and that limit is now reached with our present conditions, for the reason that any imperfection in the alignment of the road has a correspondingly increased effect in developing swaying or side motion in the engine at high speed, which, when developed, is more intense and more lasting than with lower built locomotives.—**J. C. Inglis, M.Inst.C.E.,** *Proc. Inst. C E. (Eng. Conference,) Sect. 1, Vol. CLIV.—C. S. L.*

Automatic Signalling.

THE author gives a brief discussion of the present position of automatic railway signalling, and explains by diagrams the arrangements for "track-circuit working" which are most commonly in use. The introduction of these systems, depending for their action upon the short-circuiting by the wheels of the vehicles of a low voltage electric current running along the rails, gave a great impetus to automatic signalling, especially in the United States, where in January, 1902, there were 3,354 miles, on 40 different railroads, so worked. In this country the L. and S. W. Railway has adopted an electro-pneumatic system on the main line between Andover and Grateley (5½ miles), and the N. E. Railway is installing the Hall system on its main line between Alne and Thirsk. In America, electro-pneumatic systems generally use air at 80 or 90 lbs. pressure per sq. in., but on the L. and S. W. Railway the pressure used is only 10 to 20 lbs. per sq. in. In this system power-houses and air-compressors have to be supplied at intervals along the line, pressure being conveyed thence in pipes running the whole length of the installation, with branches to all signals. The pressure acts on a piston to which is connected a rod actuating the signal arm. The pressure is admitted to the piston, or shut off from it, by a pin-valve actuated by an electro-magnet in circuit with a signal-battery, which again is under the control of the track-battery circuit. As used on the L. and S. W. Railway, the signals normally stand at the "clear" position. When a train enters a section it puts to "danger" the signal at the entrance to that section, and maintains it in that position until the train passes out of the section *in advance*, when the current is re-established, and the arm is pulled off. On the N. E. Railway system, the power is stored at the foot of each signal-post in the form of liquefied carbonic-acid gas, at a pressure of about 800 lbs. per sq. in. There are two cylinders to each post, and each cylinder will suffice for 6,000 to 7,000 operations of the signal, the working pressure being about 50 lbs. per sq. in. On this line the normal position of the signals is "danger," and they are brought to "clear" by an approaching train, and restored to "danger" when the train has passed. The independent supply of power to each signal is probably more economical in first cost than a continuous supply of power over great lengths of line from a central power station, but it has yet to be determined whether it will be as economical in maintenance and as reliable. Mention is also made in the paper of the Miller and the Boult systems, which give their signals in the cab of the engine. The former is in use outside the Grand Central Station at New York, and also at the west end of the Woodhead Tunnel on the Great Central Railway. —**W. J. Cudworth,** *Engineering Conference, Section I. (Railways), (Vol. CLIV., Proc. Inst. C.E.).—W.C.H.*

Recent Improvements in Canal Engineering.

PARTICULAR attention has recently been directed to electrical haulage and propulsion, and several systems have been tried with more or less success. In France M. de Bovet carried out experiments in 1894, on the St. Denis Canal, with an electric motor placed on a 300-ton barge, supplied with current from overhead wires on the towing-path, and actuating a drum which picked up a chain laid on the bed of the canal. The "Galliot" system, used on the Burgundy canal in 1894-1897, consists of two parts, an electric tricycle on the towing path, supplied with current from an overhead wire and a rudder-motor. The tricycle is capable of towing two barges loaded with 700 tons at a speed of 1¼ miles

per hour, and the rudder-motor drives a screw-propeller. The system has also been tried on the canal between Douai and Bethune. The cost of haulage is said to be 0·038*d.* per ton, or about half the cost of horse haulage. In Belgium the "Gerard" system has been in operation since 1900 on the Charleroi Canal. The haulage used to be performed by horses at a speed of 1½ miles per hour and at a cost of about 2*s.* per boat-mile. By electric haulage the speed was doubled, the cost remaining about the same. The system consists of a four-wheel electric carriage of about 5 h.p., the current for the three-phase motor being taken from overhead wires from three separate trolleys. The generating stations are 29 miles apart, and sub-stations, 3 miles apart, reduce the current to 600 volts. Electric tugs have also been employed, to which current is conveyed through an insulated cable, supported by a boom on the mast. The tugs tow two boats of 70 tons each at a speed of 2 miles an hour. In Germany Messrs. Siemens and Halske have experimented with a rack-rail electric locomotive, supplied with current at 500 volts from an overhead wire. The rack-rail serves as a conductor for the return current. In England the Gerard system is being tried on the River Lea. The Thwaite-Cawley system consists of an aerial railway about 10 ft. above the towing path. There are two rails, on which run four-wheel electric motors. The cost of haulage is given as 0·032*d.* per ton-mile for a speed of 2½ miles per hour. In Holland barges propelled by petrol-engines have recently been tried with very satisfactory results.—**G. FitzGibbon,** *Proc. Inst. C.E., Vol. CLIV., Eng. Conf., Sec. II., June, 1903.*

Deep-Level and Shallow Subways.

THE special advantage of shallow subways is that passengers can reach the trains without the necessity for using lifts and foot-subways; and another great advantage is that the ventilation is very much easier than in deep-level subways. They may be described as self-ventilating. The disadvantage of shallow subways is that below the surface of the streets there is encountered such a haphazard accumulation of sewers, gas and water-pipes, telegraph and telephone mains and electric-light cables, as to render construction very expensive. The author advocates, for the accommodation of urban railway traffic—(1) overhead railways in back streets, where compensation would be immaterial and their unsightly appearance would not be objectionable; (2) shallow subways where they can be constructed and the cost is not prohibitive; (3) deep-level railways. The author has assumed in all these cases that the operation of the railways would be by electricity.—**S. B. Cottrell,** *Eng. Conf., Sec. I., June, 1903, Proc. Inst. C.E., Vol. CLIV.*

MECHANICAL.

Electric Driving in Machine Shops.

THE general arrangements with which the author is acquainted are:—1. One motor per works: This replacing of a steam or other engine by an electromotor is foolish, as a gas, oil, or steam engine would always give a more economical and equally satisfactory drive. 2. One motor per tool: This arrangement is, as a rule, not the best, as although the cost of the current is reduced very greatly, it is at the expense of interest and depreciation, and it is difficult to imagine a shop where all the tools would be benefited by speed control other than that obtained by cones, etc., or where many tools could not be grouped without loss of efficiency. 3. One motor per line-shaft: This arrangement leads to a certain amount of economy in large works generating their own current, but is decidedly bad where current is purchased, as oil or gas engines would give a more economical drive. In either case the advantages peculiar to electric driving are not secured. 4. Mixed arrangement developed from No. 3: In this arrangement one motor per shaft is employed as far as possible without involving long lengths of idle shafting, and a few tools may have separate drives on account of their inaccessibility. 5. Mixed arrangement developed from No. 2: This arrangement, which appears to the author to be the only reasonable one, may be described as one in which each tool having a large percentage of idle time, or which would benefit by a variable-speed control more delicate than that given by the usual mechanical means, has its own motor, and the remainder are grouped, not in any hard-and-fast way as so many tools per motor, but in larger and smaller groups in such a way that the sum of the interest, depreciation, attendance, repairs and current cost shall be a minimum.—**A. B. Chatwood,** *Jnl. I.E.E.*, Paper read May 7, 1903.

Machine Tool Feeds and Drives.

THIS is the fifth article of a series on "Machine Tool Progress." The writer says that the most extensive use of the positive-drive variable-speed mechanism has been made for the feeds and for the main drives of the Bickford radial drill. The manifest advantages of the gear-drive mechanism over the cone-pulley-and-belt method of driving offer strong

inducements to its use on main drives and it has proved very successful in this application. The main drive of the Bickford drill is through two independent change gear mechanisms, one at the base of the column, and the other at the rear of the arm. The main speed box receives power on pulley, and delivers to a vertical shaft within the column. The vertical shaft drives back gear box through gears at the top of the column and a splined shaft extending down along the rear to permit vertical adjustments of the arm; from the back-gear mechanism the drill spindle is driven direct. Four speeds are also available from the back-gear box. This device consists of a three-shaft change-gear arrangement in which two double-throw clutches are operated by two handles. This device is similar in principle to a four-speed change-gear mechanism described in a previous article of this series. Friction clutches are used in this device to permit clutching and disengagement without noise or shock while the machine is running. It is arranged so that each speed transmits to the spindle more than double the pulling power of the next faster speed. The two devices described afford a possible variation of sixteen different speeds, capable of easy and instantaneous changes, and attended with no interruption of power, as is necessary with belt changes. In this way, aside from many other advantages, the gear-drive mechanism is far superior to the older cone-pulley-and-belt method of driving. The capacity of the drill with positive drive and feeds is remarkable—a 1½-in. drill has been driven at a feed of ·035 in. per revolution of the spindle through ·45 carbon steel.—**C. W. Obert,** *Am. Eng. and Rlrd. Jnl., May 1903,* pp. 178-179.

APPLIED ELECTRICITY.

An Electrical Method of Preparing Nitrogen Compounds from the Atmospheric Air.

IT is a striking fact that, in spite of its great economical importance, little attention should so far have been paid to the problem of producing the union of nitrogen and oxygen by means of the electric spark. In fact, the author thinks this problem to be one of the most important of modern electro-chemistry and electrical engineering. The results recorded by English and American experimenters are rather of a qualitative nature, not allowing of any accurate conclusions being made. After giving an historical sketch, the author proceeds to expose the common features noted in sparking methods. Atmospheric air (20·8 per cent. of oxygen, 79·2 per cent. of nitrogen) is drawn through a high-tension sparking gap, when the nitrogen molecule, N_2, at the high temperatures will be destroyed, and oxydation occur with the oxygen present in the air, according to the equation,

$$N_2 + O_2 + 2 \times 21{,}600 \text{ cal.} = 2\,NO, \text{ or}$$
$$N_2 + O_2 + 50{\cdot}1 \text{ watt-hrs.} = 2\,NO,$$

the oxydation thus being an *endothermic* re-action, requiring a considerable amount of energy. The state of equilibrium of the resulting gaseous mixture is given by Guldberg & Waag's "Law of Mass Effects," the equilibrium constant having recently been determined by W. Muthmann and H. Hofer ("Berichted d. Deutsch. Chem. Geo.," 1903, Vol. II., p. 438). As, however, the results of these experimenters are greatly impaired by an error of calculation, the author gives the corrected values. It is shown that to produce 30 gram., of NO, 0·55, as against 0·3954, kilowatt-hrs. are required, giving a total of 8,745 kilowatt-hrs. = 12 h.p. in producing 1 kg. of nitric acid (477 gram. of NO), which would mean a cost of 3d. The author thinks these corrected figures to afford a means of improving the *efficiency* of the process. The co-efficient of equilibrium, which controls the output in NO, will, in fact, vary to a high degree along with the temperature, according to Vant' Hoff's equation. It is shown that the output will increase rapidly with the temperature of the reaction furnace, reaching at 2,115 degs. Cent. twice, at 4,000 degs. Cent. twelve times the value obtained in Muthmann's experiments. The question next arising is how a reaction furnace, capable of giving so high temperatures, may be realised. The author thinks the reaction to be due to a purely thermic effect, not necessitating the presence of electric sparks. He accordingly suggests using heat generators in the form of resistances (or electrodes made of second-class conductors) heated by electricity. Nernst filaments, for example, would readily give temperatures exceeding by some hundreds of degrees that of spark gaps, thus corresponding with an output twice as high. A more efficient means of increasing the output would be to use electric arcs, as produced between fused second-class conductors (metal salts, etc.), by a convenient arrangement of the electrode vessels and terminals. Photometric measurements of these singular electric arcs give evidence of the exceedingly high temperatures thus produced, which are much above that of carbon arcs, the latter being unsuitable owing to its reducing antagonistic effects. At the temperature of carbon arcs, 46 per cent. of the atmospheric air would be converted into nitrogen oxides, yielding nitric acid.—**Ewald Rasch,** *Dingler's Polytech. Jnl., Vol. CCCXVIII., No. 17,* pp. 1–15, *April 25, 1903.*—*A.G.*

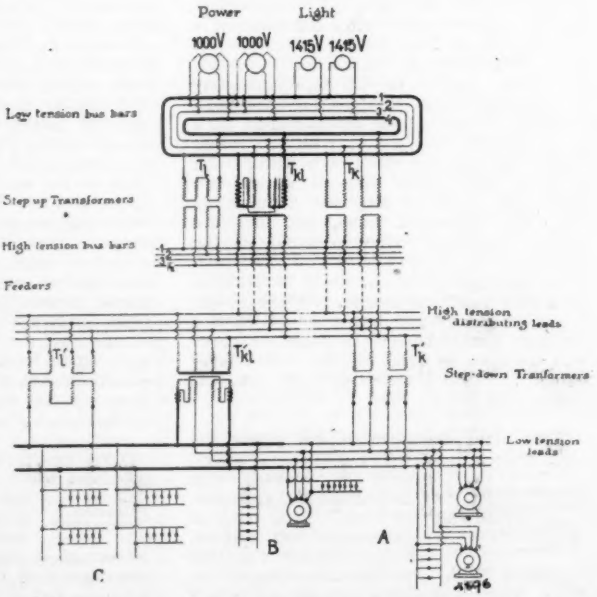
The Arnold-Bragstad-La Cour Polycylic Power-Transmission System.

DR. FREDERICK BEDELL showed first how, at points of equal potential of a power transmission system, currents of various characters, especially continuous current, can be sent in and taken out without influencing thereby the existing currents. The arrangement given by Dr. Bedell was described for a practical case by Mr. A. S. MacAllister in this *Journal*, February 28, 1903.* The Arnold-Bragstad-La Cour distribution system, illustrated in Fig. 2, was worked out in the Electro-technical Institute of the Technical College at Karlsruhe independently of the above-mentioned invention, and its principal characteristics are the following:—1. Machine installation separate for light and power, consequently separate speed and voltage regulation, different frequencies, abolition of phase displacement in the lighting machines. 2. Bus-bar system in common for lighting and power, hence the simplest arrangement of apparatus. 3. Step-up transformers are either (*a*) separate for lighting and power, but able to be switched over according to need, in which case single-phase transformers of ordinary construction are used: or (*b*) combined for lighting and power, but in such a manner that the two functions do not mutually influence one another. This latter arrangement offers some saving in material, but necessitates a special construction (four-core apparatus). 4. High-tension bus-bars are common, but independent of one another for light and power. 5. High-tension mains are likewise common, but independent for light and power. With equal effective e.m.f., the current-carrying capacity of the wires is increased by 50 per cent. over the single or two-phase systems, and by 12·5 per cent. over the three-phase. With respect to the effective e.m.f. to earth, all systems are equal. The same applies to high-tension net-work. 6. Step-down transformers are, according to requirements of the individual districts to be fed, either only for power, only for lighting, or combined. 7. Distributing system, according to requirements, either with four wires for light and power, or with two wires for light alone. All lighting installations are made in the simplest way, with only two wires; they are hence cheaply installed and maintained. Since the voltage variations produced by the motors do not in any way influence the light, motors up to any desired size can be connected; motors with short-circuit armatures (without starters) of much larger sizes than formerly can be installed. — **O. S. Bragstad,** *Elec. Wld. Vol. XLI., No. 19*, pp. 786–788.

* See FEILDEN'S MAGAZINE, May, 1903, p. 462.

Motor-Starting Switches.

THERE are three types of resistance in use—(1) The radiation type, (2) the absorption type, and (3) liquid resistances. When properly rated the absorption type will stand overloads for a short time just as well as the radiation type of resistance. If starting is repeated at short intervals the sand or cement does not dissipate the heat, and sooner or later the wires get burnt. When the wires are exposed to the air it



THE ARNOLD-BRAGSTAD-LA COUR POLYCYLIC POWER-TRANSMISSION SYSTEM.

is possible to tell by inspection whether they are being overheated, but with absorption resistances one has to trust in the maker's statement. For use in exposed situations and for large powers a starter with liquid resistance has many advantages, and if proper care is given to the design it will give less trouble on the whole than a wire-wound resistance. It is true that liquid held in an open box evaporates and needs replenishing from time to time; but this small amount of attention is more than balanced by having a resistance that will not burn out, however heavily it is overloaded. In order to give satisfaction to the general user, the liquid starter must be provided with an overload and a "no-volt" automatic release. If a no-volt release cannot be used conveniently, the main double-pole switch must be interlocked with the resistance, so that the current cannot be switched on while the resistance is cut out. In discussing the type of resistance that is best suited for a particular purpose, it is convenient to distinguish between frequent and occasional use, and the same classification can be applied with advantage to the switch work. Where the switch is used often, too much stress cannot be laid on the importance of strong construction, with the contacts and all wearing parts renewable from the front; but for occasional use the use of a heavy switch construction is not necessary. The danger is that, if we admit a light switch construction in certain cases, some matters of vital importance may be neglected in the struggle for cheapness. Switches exposed to the weather must have a water-tight case, not only for the resistances, but also for the switch work. The ordinary patterns of ironclad starters are admirably fitted to keep the damp away from the resistance wires, but they are seldom designed so as to admit of the addition of a cast-iron cover over the switch front, although this could easily be arranged at a very small extra cost. Where covers are used the switch lever should have a separate handle bushed through the cover and engaging by a pin with the switch lever inside to make a water-tight job.—**A. H. Bate,** *Jnl. I.E.E., 1903.*

Applications of Electricity in Engineering and Shipbuilding Works.

THE plant described in this paper has been erected in the works of Messrs. Vickers, Sons & Maxim, and amounts in the aggregate to about 22,500 b.h.p of generators and motors, being installed at the Sheffield, Erith, and Barrow works of the firm. The use of single motors has proved of great convenience in placing machines, rendering them independent of the line shaft; it also allows a free space to the travelling cranes to work in by dispensing with the network of overhead belting. As regards actual efficiency, during working time there is little to choose between line-shaft driving and separate motors. The machinery driven includes lathes, boring, drilling, planing, slotting, and shipyard plate machines, metal saws, wood-working, and various special machines, cranes, fans, and blowers. The difficulty of stating the saving in terms of simple comparison is very great, but at Barrow the actual result was a saving of half the coal bill, with an increase of over 50 per cent. in output. In no other department is it possible to express so direct a comparison. The author points out, however, that electric driving will not necessarily cheapen production in all cases; and it is only where the conditions are favourable that electric driving can replace the older system economically in parts of the country where coal is cheap. An example given by the author is that of a small compact factory, in three stories, covering but a small ground space. The steam pipe was very short, and the losses were chiefly in the shafts and belts. As the machines were many and small, it would have been impossible to dispense with the shafts, and only the main belts from floor to floor would have been saved by motor driving. Had the works consisted of isolated shops instead of floors, the case would have been entirely favourable for electric driving. The number of stand-by men in works dealing with heavy weights can be greatly reduced by the judicious use of motors. A few years ago it was usual to keep a gang of men to do such jobs as opening furnace doors, and on the large furnaces six men were required to raise some of the heavy doors. Now this operation is performed by a 1½-h.p. motor, and only as many men are employed as can be kept fairly busy. The author thinks that the future applications of motor driving will be largely in the direction of doing all the rough, heavy work which is now left to labourers. A man can do work which a motor cannot, and he should be set free to do that work.—**A. D. Williamson,** *Trans. I.E.E.*, Paper read May 7, 1903.

Wireless Telegraphy.

THIS paper sets out briefly some of the problems which must be solved before the full advantage of wireless telegraphy can be obtained in commercial practice. The most important is the problem of isolation of messages, and for its solution two methods, syntonic and optical respectively, have been

proposed. In the syntonic method, as the vertical wire or network must radiate equally in all horizontal directions, frequency alone is available as a means of discrimination, and theoretically a high degree of privacy seems possible ; but as there is no property in special wave-lengths, syntonic messages must always remain open to interception over a large radius by syntonised instruments or by untuned instruments at closer quarters. Superposed interference signals, to prevent interception at close ranges, do not provide a final solution of the difficulty. A closed-circuit system with two syntonised coils, one for transmitting and the other for receiving, admits of sharper tuning, and with vertical coils secures an element of direction, but it is deficient in range. The optical method, involving the use of lenses and reflectors in connection with Hertzian waves, has received too little attention, as a reliable system of this kind would give great privacy and, even if it were limited to a ten-mile range and an accuracy of 50 per cent., would be of the greatest importance in practice. In his general remarks the author points out the serious bar to progress constituted by the lack of a satisfactory metrical detector, and the difficulty arising from want of strict isochronism in the oscillations of the condenser discharge, by which all wave-trains are produced, and suggests that there may be possibilities of progress in the use of two or more radiators in suitable phase-relation to reinforce waves in a particular direction, in the creation of stationary waves or nodal areas, and in the employment of the earth's free period.—**E. A. N. Pocbin,** *Engineering Conference, Section VII. (Applications of Electricity), (Vol. CLIV., Proc. Inst.C.E.).—W. C. H.*

Batteries and Coils for Gas-Engine Ignition.

THE usual ignition outfit consists of a primary battery and spark coil, but widely different results are obtained. Some engines run for a year on one charge of the battery ; others require that the battery be renewed in three months, or less time. Much depends on the internal resistance and number of cells. Many have an idea that the more cells they connect in one series the longer the battery will last, while in reality just the opposite is true. If the internal resistance of the battery is small and discharge takes place under similar condition, ten cells will run down twice as quickly as five. Hence it would cost four times as much to keep up as a five-cell battery. Many engines permit the sparking points to be in contact for a considerable portion of a revolution before they produce the spark. If the battery tends to polarise rapidly the spark may be very weak, owing to the fact that the battery has given up its best current before it is called upon to produce the spark. Much depends upon the spark-coil used. For economical ignition a good spark-coil is imperative. It has been shown that the current flowing depends directly on the resistance of the spark-coil and external circuit—that is to say, if the resistance be doubled but half the current will flow, and hence the battery will last just twice as long. To renew the battery usually costs more than the price of two or three good spark-coils, yet some engine builders persist in sending out good batteries and cheap coils. That the cheap, low-resistance coil will give a good spark one can rest assured ; but the fact must not be overlooked that the spark is produced by the large quantity of current which flows, and not by the efficiency of the coil itself. On the other hand, with a high-resistance coil, it is possible to secure just as good a spark with half the amount of current.—**G. W. Frost,** *Amer. Mfr. & Iron Wld., Vol. LXXII., No. 21*, pp. 595-596.

Rôle of Earth in Wireless Telegraphy.

IN the earlier stages of wireless telegraphy an important part was ascribed to the earth, as all the devices had to be carefully earthed. As, however, the Braun system showed earthing to be apparently unnecessary, most experimenters would adopt opposite views, the transmission of electrical waves being considered as analogous to the propagation of luminous waves. The fact that the curvature of the earth should be so easily overcome was, it is true, an enigma unsolved. It is the more difficult to decide this question, as even with Braun's system the co-operation of the ground is never wholly to be dispensed with, the heights attained in studying the problem being, on the other hand, too small as compared with the dimensions of the earth. In order, however, to arrive at a partial solution, the author endeavours to show that the effects exerted on the earth by an ordinary transmitter are such that her electrical potential is influenced by them to a marked degree, the working of the most sensitive receiving station being explained in this way. It is shown that the earth has by no means an electrostatic capacity of extreme magnitude, it being equivalent to the radius of earth, viz., $6{\cdot}37 \times 10^8$ cm. or 708 microfarads. The author gives a theoretical proof of the possibility of disturbing, in a noticeable manner, the potential of a sphere of this capacity with the limited resources of modern wireless

telegraphy. If the author's theory were true, Marconi's system would turn out to be an *earth telegraphy*. In concluding his deductions the author is compelled to confess the boldness of his theory.—**Dr. A. Koepsel,** *Dingler's Polytechnisches Journal, Vol. 318, No. 25,* pp. 385–388.—*A. G.*

The Development and Use of the Small Electric Motor.

THIS is the third article of a series in which are discussed the history and economy of the electric motor, and its adaptation to the machine shop. The preceding article, in May, referred particularly to the driving of machine tools, and the power required for standard tools and operations. The present article is devoted to various applications of electric driving to a wide range of manufacturing operations, among which may be mentioned the driving of lathes, air compressors, hoists, shapers, drills; planing, grinding and slotting machines; punching and sharpening presses; and wood-working machinery.—**Fred. M. Kimball,** *Eng. Mag., Vol. XXV., No. 3,* pp. 374-398.

LIGHTING, HEATING, and VENTILATION.

Heating and Ventilating Shops.

AT a recent meeting of the New York Railway Club there was a discussion about heating railway shops. While such buildings are simple in construction, the problem of distributing heat and air is not simple. If the heat is applied directly by steam or hot-water coils the vicinity of the coils is apt to be uncomfortably hot, while places at a distance are disagreeably cold. The heat imparted to the air is largely lost and goes to the roof and skylights, and there is also no ventilation. The direct system of heating is being superseded by the fan or hot-blast system. The heater will contain considerably less pipe than required for direct heating, and the exhaust of the engine driving the fan is usually turned into the heater, thus obviating any loss from that source. Some examples were cited at the meeting by Mr. C. H. Gifford. He said:

> "If you desire air at any particular place, the best way is to provide a conduit to deliver it there. If there is any difficulty from the air blowing on an individual workman, it is easy to rectify it, and if you are unable to predetermine where the men or machines are to be located, you can have an adjustable discharge, and there generally is some space to which the air can be directed and cause no inconvenience whatever."

Mr. E. T. Child said that—

> "the fan system in the summer gives the opportunity to ventilate the shops. Some shops are apt to become overheated, and a current of cold air may be drawn from a basement, making them much more habitable. At the shops of the Atchison, Topeka & Sante Fé Railway Company the underground system was adopted and low horizontal outlets were provided, which distribute the air at the floor and along the walls. This is an extremely large shop, the contents being about 4,000,000 or 5,000,000 cubic feet. The shop is heated by four large apparatuses, and the underground ducts extend almost entirely around the building. The pipes are not over 3 ft. high, the air being discharged horizontally along the floor, and I understand that the building is very satisfactorily heated."

Report Am. Machst., Vol. XXVI., No. 23, p. 802.

Smoke Abatement.

AS regards industry, means for the abolition of the smoke nuisance are already in the hands of the engineer, but the problem of domestic smoke is in a less hopeful position. The author advocates the imposition of a tax on the consumption of smoke-producing fuels, or of a chimney tax, so applied as to stimulate the most radical improvement in domestic heating. The architect and the engineer would have a new field for their ingenuity and skill, and their trained efforts would greatly advance practical knowledge of the subject.—**G. T. Beilby,** *Proc. Inst. C.E., Vol. CLIV., Eng. Conf., Sec. VI., June, 1903,*

WATER AND SANITARY.

Pino's Hydroscope.

BY means of Cavaliere Pino's hydroscope, a person will be able (1) to see clearly and distinctly any object moving among waters or lying on the sea-bed, practically at any depth, and over a surface of more than 3,000 yds.; (2) to take wonderfully clear photographs of whatever he perceives there; and, therefore, (3) to recover therefrom anything he likes. All these three operations will be performed while standing in an ordinary small boat on the surface of the water. Three different types are made. The first is equipped with electric means of propulsion, and can move from one place to another. In the second case the instrument is nearly the same, but not provided with auxiliary apparatus, while in the third case it forms a part of the vessel, be it for industrial or war purposes. The simplicity of the instrument and the easy and cheap construction of it are remarkable. By an ingenious arrangement of lenses and reflectors a field of 3,000 sq. yds. can be photographed from the one position. This can be done either by day or night, because during the night or when an enormous depth must be reached artificial light is supplied through powerful electric lamps provided with strong reflectors, made of a special form as well as of a special crystal so as to resist the enormous pressure of the water. These lamps illuminate the sea-bed only for a diameter as large as that of the field of vision. The grave question of the enormous pressure,

has been resolved by means of a system very simple in itself and easy in in its functions. The photographic or photo-stereoscopic apparatus is arranged in such a manner that these can work at any desired depth by electric power and take up either the complete field of vision or a single part of it. Pino's hydroscope enables the operator to see down in the water at a depth of two yards as well as of hundreds by the same instrument, since the focus may be changed in a few seconds by means of two different powers, one of which is electrical. The focus can be obtained or changed by moving either the lowest part of the instrument or the upper part of it; also by moving the two opposite parts of the instruments together and in an opposite direction. The writer adds that his readers will shortly be able to judge of the actual working of the instrument when public experiments will take place in English waters. —**Dr. Carlo Iberti,** *Elec. Eng., June 5, 1903*, p. 835.

Investigation of the River Severn in the Shrewsbury District.

THE bacteriological analyses of the officers of the Royal Commission having shown that the effluents from bacterial methods of sewage treatment usually showed insufficient purification as measured by the "Coli" and "Enteritiditis Sporogenes" tests, it was considered of primary importance to ascertain the risk of allowing such effluents to pass into streams and rivers. As a suitable river into which a biological effluent passed could not be found, it was determined to carry out the investigation upon the River Severn at Shrewsbury. The only disadvantage was that crude sewage and not an effluent passed into the river. But the bacterial problems in the two cases were closely similar. Commencing with the watershed, the numerous analyses which have been conducted during the past three years show that the B. coli is present in the proportion of 1 per c.c. in the feeders of the River Vyrnwy. An extensive analysis of the mud of the lake and of the soil of the watershed also shows the absence of the B. coli. Numerous small brooks which enter the Severn reveal evidence of definite contamination, but that the land drains are comparatively free from pollution. This is very interesting, for undoubtedly the brooks are liable as they pass close to human habitations to contamination; whilst the land drains, removing the water from pasture and arable land, are isolated. Lastly, taking the River Severn above the great source of pollution which occurs at Shrewsbury, we find that B. coli is present in the proportion of about 10 per c.c. Between Vyrnwy and Shrewsbury there is a gradual contamination, every brook which contributes to the volume of the Severn as it passes through the more thickly-peopled districts adds a small number of B. coli, and at certain places, like Welshpool, there is considerable direct contamination. Thus the streams of the watershed may be taken as the standard of purity and as furnishing water which is harmless to drink; that of the Severn above Shrewsbury as slightly polluted, and as water which should be subjected to filtration before being consumed. — **Prof. Boyce and Drs. Grunbaum, MacConkey, and Hill** (*Report Roy. Com. Sewage Disposal*), *Pub. Health Eng., Vol. XII., No. 315*, pp. 544–545.

WORKS MANAGEMENT.

Fitting and Erecting-Shop Management.

IT is undoubtedly an advantage to have a few benches suitably placed in the erecting-shop, as there are a number of jobs in erection in which a vice is indispensable, and several portable vices will generally come in handy in the neighbourhood of a large machine in the course of erection; but these vices are not for the use of the fitters. The section in the works where the fitting proper is carried out should always be treated as a separate department in works of any size, even where it is necessary to have the fitters and erectors working in the same shop. If a sufficient number of fitters are not employed to warrant the appointment of a departmental foreman, a charge-hand over the whole of the fitters' benches is to be recommended; and the saving in time effected by keeping the fitters at their vices, instead of walking about the shop after work, will alone often cover the wages of the charge-hand. It is surprising what a number of firms adhere to the old-fashioned idea that it is an advantage to appoint a "working foreman," being apparently under the impression that they will get a day's actual output and a day's work of supervision over the other men for one man's wages. The foremen or the under-foremen, who are chosen as possessing the most specialised and really practical knowledge in their own departments, should not, in addition to their other duties, be expected to handle a hammer and chisel or a file. The use of the limit gauge has been found to be of the greatest advantage in the machine-shop. The principle involved in its use is that the extent of the allowable error is arbitrarily fixed. The same principle should be applied on the fitting benches—that is to say, the man working on any job should be told, whenever practicable, what will be the

maximum error allowed. The introduction of the limit gauge has effected an enormous saving in the production of repetition work, and the principle involved in its use can be applied where the application of the limit gauge itself is impracticable. — **C. L. Browne,** *Mech. Wld., Vol. XXXIII., No. 855,* p. 248.

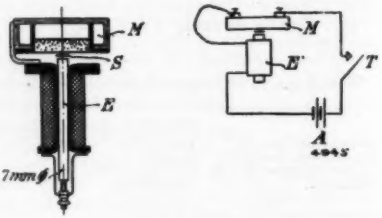
Lifting Electro-Magnets.

THE electro-magnet is now being put to a comparatively new use in lifting and transferring loads of various sizes. The familiar hook and block is replaced by a mass of metal, connected with the generator by wiring, the magnet usually being constructed with one coil and one centre pole, while the two outside poles with the plate connect the three together. The ends of the coil through which the current passes come through the top of the plate and are connected across the line. The magnets are sometimes made with several poles and coils connected in series. The mechanism is similar to the usual crane, but at the elbow of the motorman is a special switch for controlling the electro-magnet. If a slab of steel or a plate of iron is to be handled, it is only necessary to run the crane to a point above it and lower the chain or cable with its magnet attached. When the magnet has been lowered sufficiently it is energised by the application of current and holds the load until it is raised, carried to its other position, and when the current is turned off the magnet instantly releases it. The time and labour required in fastening loads to the block of the ordinary crane are entirely saved. After the magnet has a grip upon the iron or steel it can be handled with the aid of but one man besides the motorman, merely to guide it into position. Here again the services of the hands are dispensed with, since with the electric current turned off the load is automatically released, and it is calculated that the time and labour saved represent nearly 50 per cent. in the cost of handling. A magnet of sufficient power will pick up three or four plates if desired, transferring the lot as readily as one piece. It can be used in repiling merely by applying it to the edges of the sheets or plates, which can be again deposited in such regular order that the services of one man are merely required to "even up" the heaps. As yet the electro-magnet service has been confined to handling comparatively light loads, but its capacity is only limited by the size of the magnet and the current provided.—**D. A. Willey,** *Elec. Wld., Vol. XLI., No. 24,* p. 1009.

MISCELLANEOUS.

Production of Wave Currents by Microphones.

THE excitation of wave currents, due to the juxtaposition of telephones and microphones in the usual telephone schemes is a well-known phenomenon, resulting in more or less distinct sounds given out by the telephone. Many suggestions as to a possible utilisation of this phenomenon having been made, the author investigates the conditions necessary to produce a continuous sound. The arrangement



PRODUCTION OF WAVE CURRENTS BY MICROPHONES.

shown in Fig. 1 allows of a continuous vibration of the membrane being produced, with a difference of the two phases equal to $\frac{1}{4}$ of the wave length of the resulting wave current. *M* is a microphone, *S* an iron disc about 0·1 mm. in thickness, *E* an electro-magnet of about 300 spires, *A* the storage battery, *T* the key. A Helmholtz formula may be used to determine the period; the time of oscillation of the wave current is shown to be a simple function of the self-induction of the circuit. The easy variability of the period, as well as the sinusoidal character of the current waves thus produced, are essential advantages, as compared with tuning-fork and string interrupters. A possible application in Mercadier's multiplex telegraphy, as well as for measuring purposes (comparing and measuring self-inductions), is finally suggested.—**R. v. Lieben** *and* **E. Reisz,** *Elektrotechnische Zeitschrift, Berlin, XXIV., No. 26, June 25, 1903,* p. 497.—*A. G.*

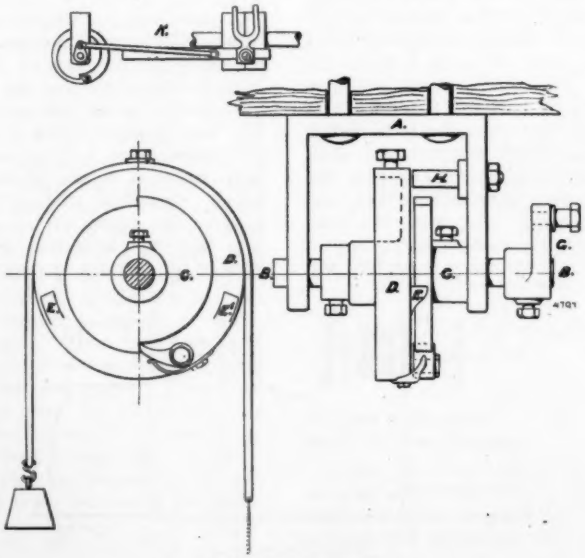
For list of Publications regularly reviewed see pages 64 and 65 of the previous number.

WORKSHOP PRACTICE.

This supplement is set apart for the discussion of matters relating to Works Management, Tools, the Machine Shop, Foundry, Pattern Room, and General Practice, both Mechanical and Electrical. It is of prime interest to Works Managers, Foremen, etc., from whom contributions, which are paid for, are cordially invited. In addition an award of One Guinea is made for what, in the opinion of the Editor, is the best contribution of the month.

A Starting Arrangement.

THERE are many ways of stopping and starting a lathe or other machine. Our way was, formerly, to have two chains hanging from the ends of a double lever with weights attached to the bottom. To start, the man pulled one chain; to stop, he pulled the other (we will say pulled, though occasionally he had to swing on the chains, the levers being too far over centre). Some time ago a boy got his jacket fast on the rough shaft he was turning. Held by the jacket he could not reach the chain himself, so shouted for help. The next boy rushed to the chains, and unhappily seized the wrong one. There was a few seconds confusion and then the lathe was stopped. But had it not been that the jacket had partly torn, those few seconds confusion would have made the difference between a narrow



A STARTING ARRANGEMENT.

escape and a serious accident. This occurrence and other considerations convinced us that something better was needed, whereupon the following device was planned and constructed. It may be that it is already in use, but as I have never seen it I conclude that the idea will be new to most. A bracket *A* is made of suitable shape for securing near the shipper-bar; the shaft *B* passes through it, working freely in its bearings. On the shaft *B* is secured the cam *C*, also the crank *G* at the outer end. The disc-wheel *D* revolves freely on the shaft, but is checked in its movement by the stops *E* coming in contact with the stud *H*. A catch swivels on a stud in the disc-wheel and engages with a tooth of the cam. A strap passes over the rim of the wheel and is secured to the wheel by a set-screw; one end of the strap carries a small weight, the other end has a cord with handle attached. The crank *G* is connected by a rod to the shipper bar as in *K*. As shown in the sketch the strap fork is in mid-position. By pulling down at the handle, the cam is turned through a quarter of a circle until the snug *E* meets the stud. The crank is now on dead centre, the strap on the fast pulley, and the lathe started. The operator lets go the handle, the weight swings the disc-wheel round, until the snug *E* meets the stop stud. The small spring has now forced the catch into the other tooth of the cam, and the apparatus is ready for the next pull, which will turn the shaft round another half-turn and so stop the lathe. If a drag is needed to keep the shaft from turning back with the disc-wheel, an extra stop-washer bearing against the bracket and springing it slightly will afford it. It will be seen that by this arrangement the same pull at the same handle will start the lathe if it is stopped, and stop the lathe if it is started. It may also be noticed that in each position of the strap-fork the crank is on dead centre, and there can be no creeping of the fork from its position until the crank is turned.

J. H.

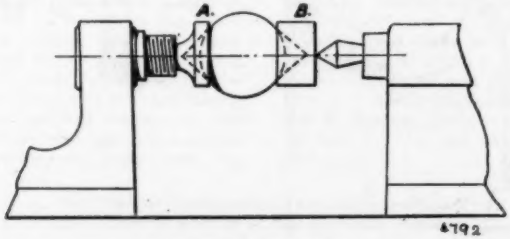
Turning Valve Balls.

The illustration shows the method of turning brass or other metal balls as used in sludge pumps and ball valves. The arrangement consists of a cup chuck *A*, made of mild steel, to screw on the fast headstock spindle or with a taper shank to fit the hole in the same. The loose headstock centre supports a floating centre *B*, which can be made of cast-iron. The tool is then set at a fixed distance and traversed across the periphery of the casting, which is moved into a fresh position after each cut. J. H. H.

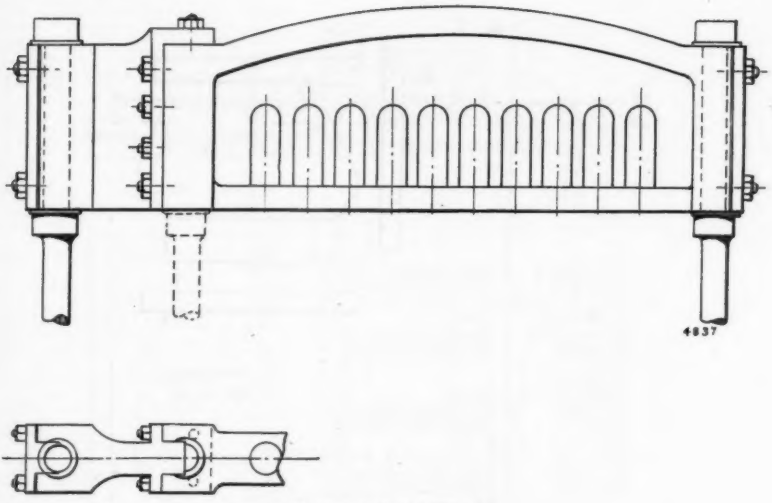
[A useful device where a circular feed is not available.—Ed.]

Enlarging an Old Press.

A short time ago we had several jobs in hand which required pressing together by hydraulic power. One of these jobs was of such dimensions that we had no press in hand which would fulfil our requirements. We had, however, lying in the yard, an old 10-ram press. This consisted of two large cast-iron blocks, or headers, one of which contained the cylinders. The tension was taken by two 4-in. wrought-iron tie-rods, which were secured to the ends of the castings by means of caps and



TURNING VALVE BALLS.



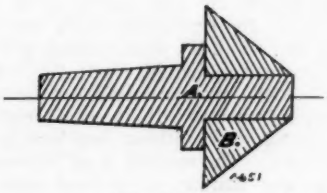
ENLARGING AN OLD PRESS.

studs. The distance between these tie-rods was, however, too narrow by about 8 ins., but we overcame the difficulty in the following manner. Two cast-iron blocks were cast of the same dimensions as the ends of the old castings, and having flanged ends so as to bear against the latter. The extension blocks were machined to fit into the recesses already occupied by the caps, and the recesses were trimmed to receive them, the cap studs, of course, being removed. The flanges of the blocks were then drilled to suit the studs which had previously held the caps, two extra studs being inserted between these, and two more in the back flange. The other end of the block was machined to receive the tie-rod and cap, studs being provided to suit the holes in the cap, thus forming a repetition of the former press end. The press was now ready for use, and was worked at a pressure of 800 lbs. per sq. in. It can, of course, at any time be reduced to its former size (that shown in the sketch by the dotted tie-rod), if required. J. H.

[Of course, the same fixings would have to be attached to the bottom of the press. —Ed.]

Large Centres for Pipe Turning.

A is turned from a piece of mild steel to fit the mandrel and poppet, with a collar left on to take thrust, while *B* is turned from cast iron or steel if convenient, and revolves free on *A* with the work, which

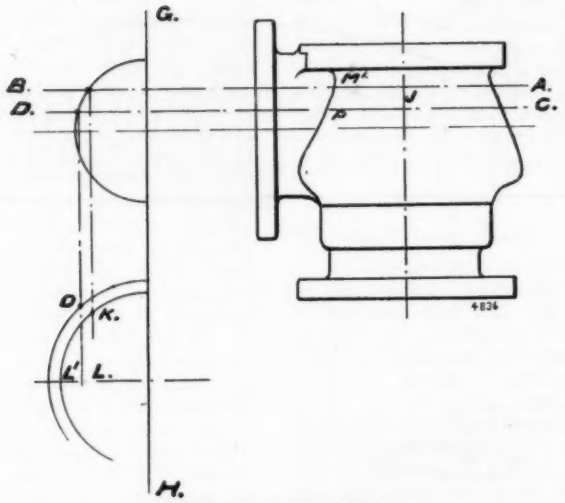


LARGE CENTRE.

runs much truer than with the usual solid centre in a rough pipe. T. H. F.

Fitting a Branch on a Valve Pattern.

In the figure is shown the method of marking off a branch for an ordinary stop-valve. Anyone acquainted with pattern-making will appreciate the gain in time,



FITTING BRANCH ON VALVE PATTERN.

and sometimes also in timber, with the above method. Instead of the much-used chalk method of fitting a branch, where the wood of the branch is carefully cut away for sometimes hours on end in large valves, the points of contact can be set out by simple geometry, and cut right away to the exact shape, and this can be done without the body having to be first finished. In large shops, where men are kept who do all the wood-turning, this last part comes very handy, as the bench-man can have the branch ready before the body is turned, whereas with the chalk method he cannot work without first having the body part. The method is as follows:—Take any number of sections such as *A B*, *C D*, etc., and draw a line *G H* parallel to centre line of body. On this line draw an end view of branch. Anywhere on *G H*, say point *H*, strike semicircles with radii equal to *J A*, *J C*, etc., and draw through points *B* and *D*, etc., lines parallel to *G H*, cutting their respective semicircles in *O* and *K*. Then from *J* set off *J M'* and *J P* equal to *K L* and *O L'*. This gives a series of points such as *M'* and *P*, which, when joined give the line to which the branch has to be cut.

C. A.

[A convenient templet is made with a piece of stiff paper equal in length to the semi-circumference upon which the height of each ordinate is marked, and the points connected by freehand.—Ed.]

A Bending Block.

Figs. 1, 2, and 3 show plan, elevation, and section of a block with attachments for bending copper wrapper plates, as used in locomotive fireboxes. It consists of a cast-iron block *B*, and a lower or back frame *F*, constructed of $3\frac{1}{2}$-in. by $3\frac{1}{2}$-in. by $\frac{5}{8}$-in. angle-iron, with two side plates, *S*, of $\frac{1}{2}$-in. steel plate, which, together with a tube or bar form a hinge. This allows the bottom frame to be pulled up to the required position, whilst the holes in the side plates permit the insertion of supporting bars. With this appliance a copper plate, 5 ins. by $\frac{1}{2}$ in. can be bent easily by three men in an hour, and if sufficient care be taken to have the pattern-block the shape required and the centre holes in their proper places, the plate will need no further setting after the bending. The pattern-block is bolted down to an ordinary levelling-block about 6 ft. square, and should be about the same length as the

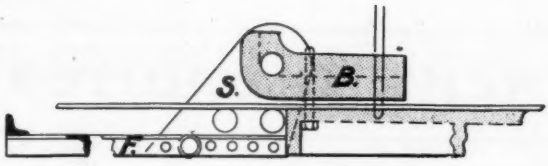


FIG. 2.

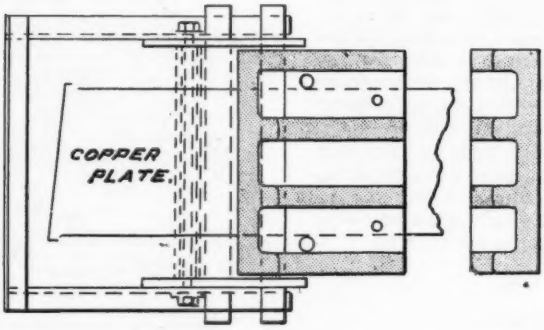


FIG. 1. FIG. 3.

A BENDING BLOCK.

levelling-block to which it is bolted, and 6 or 8 ins. wider than the plate. If desired, it can be made suitable for bending three or four classes of firebox plates with different radii at the corners. A 3¼-in. hole is cast through the block to allow a 3-in. bar to pass through; the two bolt holes for holding down bolts, and the centre holes for bars to keep the copper plate in position can be drilled. The bolts should be long enough to allow the top block to be raised about 3 ins., so that the plate can pass freely between the top and bottom blocks. To bend the plate, have the two blocks secured in their relative position by the holding-down bolts. Pass the plate between them and put the bars through the top block and copper-plate centre hole to keep it in place, tighten up the bolts and proceed to pull up the back frame *F* with crane. When it is square up lower the frame, and if the plate springs back take out the bottom roller, and pull up again, giving it a few blows to close it to the block, if necessary. Then lower back frame again and raise the top block, keeping the bolts in their holes; draw the plate out and swing the other side in position, and proceed as before.

J. A. M.

Repair to Pump Rod.

Figs. 1 and 2 illustrate the Muntz metal rod belonging to a centrifugal pump, which broke where the packing had worn it to some extent, as shown by dotted lines, Fig. 1. It being necessary to have the pump working as soon as possible, we resorted to the following method of repair. We first drove

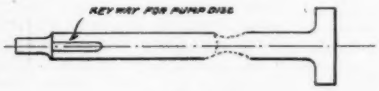


FIG. 1.

FIG. 2.

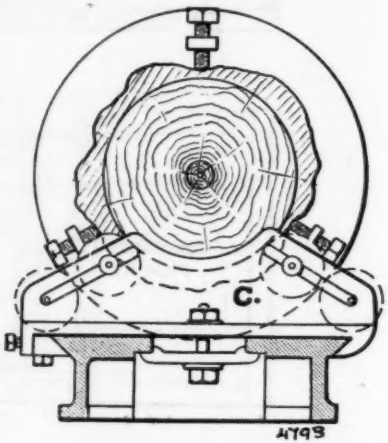
REPAIR TO PUMP ROD.

out keys, took off the pump disc, faced up broken ends of each piece of rod in lathe, drilled up centre of rod for about 2 ins. each piece, and cut 1½-in. left-handed thread Whitworth pitch. Next turned up and drilled "distance-piece," the length of which was equal to amount turned off broken ends, also cut thread in same. Then turned up piece of mild steel about 5 ins. in length, and cut 1⅛-in. left-handed thread on it, then fixed all together as per sketch, and skimmed up part that ran in stuffing-box. If the shaft was driven from the other end in the same direction, of course it would be necessary to cut a right-handed thread. This was much quicker than making a new shaft, cutting keyways, fitting keys, drilling holes, etc. It was only intended for a temporary job, but it is still running.

H. P.

Boring Wood Bowls.

In shops where a large number of wood bowls are turned the illustrated device will be found most useful and helpful in expediting the work. The log is held either in a large jaw-chuck or adjustable dogs, and a temporary centre is driven in the end, which is turned down to a convenient diameter. A low bracket *C* is set under the turned portion of the bowl, which is then free to revolve on the friction rollers as shown. The whole of the boring and the necessary recesses are



BORING WOOD BOWLS.

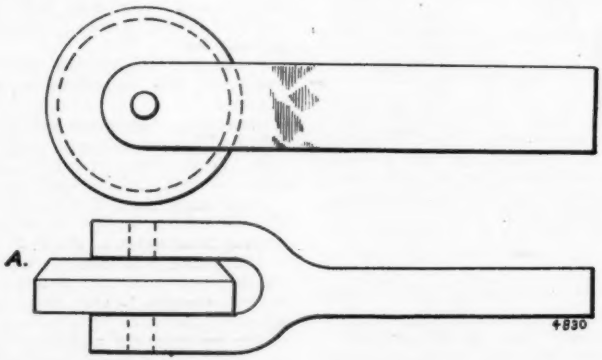
then completed, leaving the bowl ready to receive the wrought-iron gudgeons. The advantage of the stay is that the boring can be performed from both ends — a decided advantage in a long hole.

M. D.

QUESTIONS & ANSWERS.

REPLY TO J. B. *(Page 263, Vol. 8.)*

J. B. may accomplish his object by "spinning" the tube—*i.e.* forcing it down gradually in the lathe by means of a roller held in a fork tool, as shown. The tube should be fixed on a mandrel having the necessary amount of taper, and the slide or headstock adjusted to suit. The action of the roller against the periphery will spin or reduce the tube to size. The roller must be inclined on the leading side, marked *A*, with



the square-edge following. The lathe should be run at a good speed with a light feed, and a little beeswax used as a lubricant.

F. B.

REPLY TO W. W. *(Page 264, Vol. 8.)*

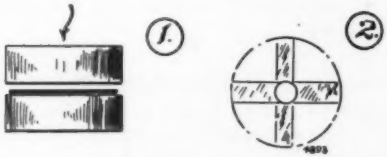
The wear and tear on the best types of electric meters is very small if properly installed and not overloaded; most of the faults arise from the gradual accumulation of dirt, which enters through imperfections in the case, and also from the partial demagnetisation of the permanent magnets, if any, which form in some meters, in combination with a revolving metallic disc, a Foucault brake which provides an adjustable opposition to the driving energy of the current being measured. This demagnetisation causes the meters to become gradually fast, which tendency is, however, more or less compensated by the retarding effect of dirt and wear in the pivots and counting mechanism, in other types of meters where permanent magnets assist in the driving, or are altogether absent, the tendency will be for the meters to become slow with age. But the chief care, from the standpoint of the commercial engineer, with regard to meters as with most forms of electrical apparatus, is rapid antiquation owing to the improvements continually being introduced by inventors and manufacturers. Most electricity-supply systems have a meter-testing department where new meters are checked before being taken over from the suppliers, and here all suspected instruments are brought and cleaned and superficially repaired by the substitution of spare parts where needed, etc.; the recalcitration which follows is usually a matter of comparative ease, given the requisite standard instruments; in this way the bulk of the meter stock can be kept in useful service by the testing staff until such time as it is profitable to replace them by improved apparatus. On most systems a meter rental is charged, the amount of which is calculated with a view to permit of repairs and replacements as required; owing to the lightness of the

metal parts and their intricacy the scrap value of old meters hardly repays for the trouble of dismantling them. J. W. B.

REPLY TO "ASPIRANT." *(Page 353, Vol. 8.)*

Hardening Saws.

Get two heavy metal blocks (cast-iron for choice)—in this case, say, about 6 ins. diameter by 2 ins. thick—with one face of each machined to a plane. Cover the machined faces thickly with oil, get the saw blood-red hot equally all over, then put it quickly in the middle of one plate and the other plate on top, oiled faces together, as at (1), and leave till cold. By getting just the right heat and plenty of oil, it should not require tempering; but if it does, polish one side—not all over, but at right angles, as at (2)—hold centrally



over a gas jet or bunsen burner, and, when the desired temper or colour is reached, drop between the plates again. F. B.

REPLY TO A. E. D. *(Page 550, Vol. 8.)*

The following is an extract from *Hogg's Guide to the Iron Trades*, pp. 378-9, which I think will give him the information he requires. By the addition of 1 per cent. to the weights, the results are correct for steel:—

"For merchant iron bars of all kinds which are rolled from the pile in one heat, one-fifth more than the finished weight is sufficient to allow for waste and cropping."

For reheating of iron blooms or slabs, allow 5 per cent. for furnace waste.

One seldom finds just what we want in books. "A. E. D." should, if he can, solve the problem upon its own merits, as the waste on different works varies a great deal. It is one of the salient points of economy in iron manufacture to reduce the waste to a minimum.

Hogg's book contains tables of areas and weights of angle-bars, T-bars, etc.

These iron bars are rolled from piles of 7 cwt. to 10 cwt. The piles are bloomed in a mill for the purpose, and afterwards reheated in a separate furnace with a sand bottom. From the reheating furnace they are rolled into the finished bar. Hogg's allowance for waste and cropping is 20 per cent. plus 5 per cent. This can, in good practice, be reduced considerably.

To obtain best results, the piles should be good and square at the ends. The furnaces should have closed ash-holes and steam-jet blowers, or their equivalent, and should be in good quick working order. The grates and fires should be kept clean, a plenum of flame should be maintained in the furnace to exclude the cold oxidising air when the door is open.

The piles should be bloomed and charged into the reheating furnaces as quickly as possible, and as soon as they are properly reheated should be drawn and rolled into the finished bar.

By careful weighing of piles, bars, and crop-ends, the minimum waste can be obtained.

Steel Bars.—There are several books published with good tables of weights of angle-bars, T-bars, etc., of which *Molesworth's* and *Iron and Steel*, by Spon, are examples.

Steel angle-bars, T-bars, etc., are rolled direct from hot ingots, the finished lengths varying from 200 ft. to 400 ft.

The soaking furnace for the hot ingots should be worked with closed ash-hole and forced draught. The area of the exit aperture should be 0·10 to 0·12 of the area of the fire-grate; a plenum of flame should be maintained in the furnace to prevent cold air entering when the ingots are being put in or taken out of the furnace. If cold air is allowed to enter the furnace, the oxidisation and waste are much increased thereby.

Under good working conditions, the furnace waste of the ingots should not exceed 5 per cent.

The finished bars being of good length and only two crop ends from each bar, the waste is much less than in iron bars.

Steel ingots cannot be made exactly to the weight required, but economy can be effected by strict supervision of the hot sawing. EXPERIENCE.